

FINAL REPORT A COMPUTER SYSTEM FOR BRIDGE RATING AND FATIGUE LIFE ANALYSIS

Research Report No. 91-2

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"The opinions, findings and conclusions expresses in this publication are those of the authors and not necessarily those: of the Department of Transportation or the U. S. Department of Transportation.

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CHAPTER I

INTRODUCTION

Bridge evaluation during the late 1970s revealed that roadways in the 50 states have just over half a million bridges. Of these, nearly 105,000 of the nation's bridges were rated critically deficient. The Federal Highway Administration (FHWA) survey shows that one highway bridge out of every five in the United States is deficient and dangerous to use. It also shows that every two days, on the average, a bridge will sag, buckle, or collapse [12,14]. The seriousness of these hazards increases each year.

Many early bridges still exist throughout the whole country and are quite serviceable when properly maintained. Thus, capacity rating and predicting the remaining service life of these bridges are necessary in order to insure their safety for the traveling public and to protect their initial investment.

Many of the structures that come under the bridge maintenance inspection problem are complex and therefore difficult to analyze for safe load-carrying capacity. The proper computer software could be a very useful aid in analyzing complex structures. Several computer-aided analysis system, like Bridge and Analysis (BRASS) (System orientation manual) [11], Bridge Analysis and Design (BRANDE) [7], and Overload Route Program (OVLOAD) [13], are available as a tool in determining the safe load-carrying capacity of bridges. All of them provided a computerized method of determining the Inventory and Operating Rating described in AASHTO Manual for Maintenance Inspection of Bridges [7] or early editions.

However, none of them can handle the calculation and prediction of the remaining service life in the steel bridges based on the fatigue analysis. Also, none of them was written according to AASHTO Guide Specifications for Strength Evaluation of Existing Steel and Concrete Bridges [2]. Because of the aforementioned weakness of these existing computer packages, a new computer system based on the new specifications from 1989 manual including the bridge rating and fatigue life analysis is especially necessary to be developed.

The general objectives of this project are (1) the development of computer package for highway bridge rating based on new AASHTO Specifications and (2) the prediction of fatigue life for highway -steel bridges by using the stress range and average daily truck traffic.

Eight different truck loads and the equivalent lane loading were introduced in Chapter II as vehicle models. Besides, beam/girder, longitudinal concrete deck/slab, and transverse deck/slab bridges in simple or continuous span structures were developed as bridge models in Chapter II. Details of bridge capacity rating method were presented in Chapter III for the aforementioned bridge models. In Chapter IV, fatigue life analysis for steel bridges was predicted by using the average daily truck traffic and the design stress range calculated from the static stress-time history. Finally, the typical, examples were studied in Chapter V. In addition, user's manuals for Bridge Rating and Fatigue Life Analysis (BRAFL) and BRAFL data plotting (BRAFL-P) Programs are given in Appendixes A and B, respectively.

This computer package will be a very powerful tool in evaluating the existing highway bridges.

CHAPTER II

VEHICLE AND BRIDGE MODELS

2.1 Vehicle Models

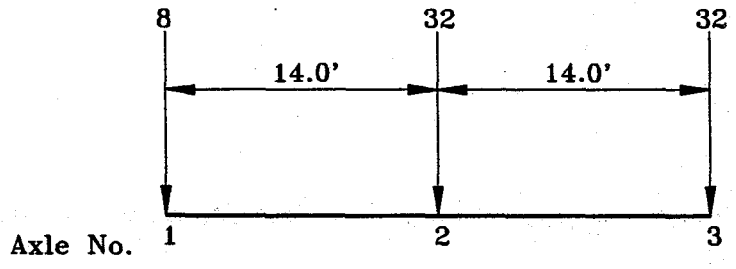
The present design vehicles contained in the AASHTO Standard Specification for Highway Bridges [10] are H 15-44, H 20-44, HS 15-44, and HS 20-44 trucks (refer to Figure 1). The H 20-44 and HS 20-44 trucks are adopted for national highways and the HS 20-44 truck in particular for the interstate highway system. Thus, these four classes of vehicles are utilized for the live loads. Besides these four loads, the Type 3, Type 3S2, Type 3-3 shown in Figure 2, and any special load are also included in the program.

In addition to the truck loading, the equivalent lane loading (see Figure 3) was used in place of the truck loadings when they produce a greater stress than the truck. In this program, only one truck is to be used per lane per span. Generally, the equivalent lane loading will produce greater stresses than the single truck in longer spans or continuous spans.

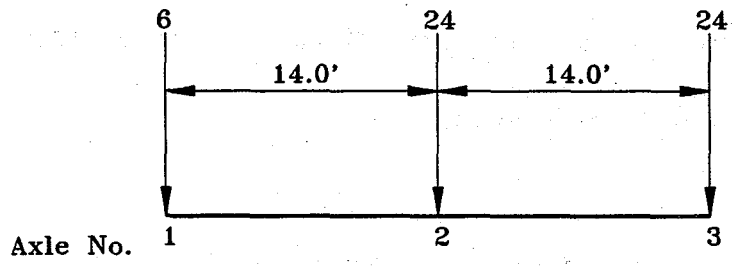
2.2 Bridge Models

Beam/Girder, longitudinal concrete deck/slab, and transversed deck/slab bridges were developed as bridge models in simple or continuous span structures. The material of bridge could be- steel, timber, or reinforced concrete. The cross section of bridge could be uniform or nonuniform. Each bridge span is assumed to have fifty equal segments for simple span bridge

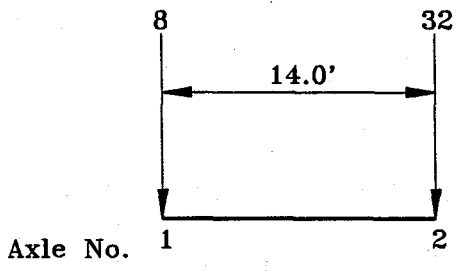
Type HS20-44



Type HS 15-44



Type H20-44



Type H15-44

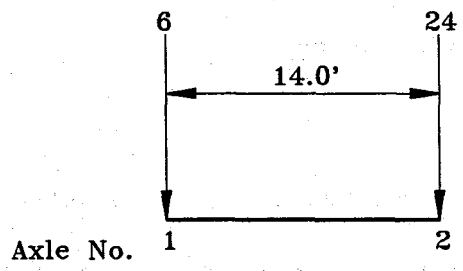
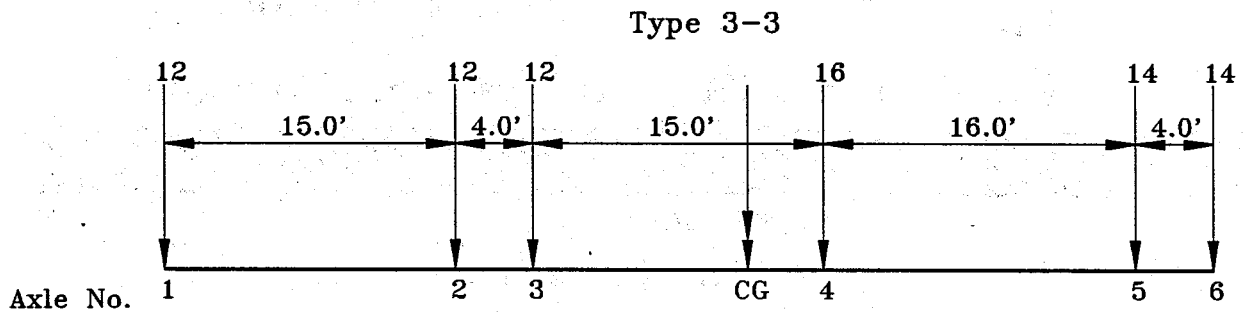
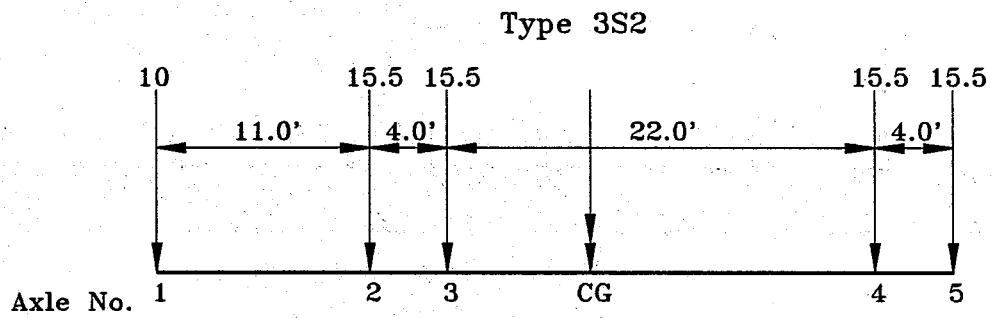
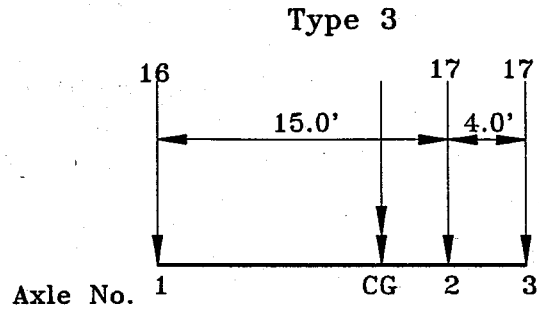


Figure 1. AASHTO H and HS Vehicle Loadings



* Indicated Concentrations Are Axle Loads in Kips.

CG = Center of Gravity.

Figure 2. Type 3, Type 3S2, and Type 3-3 Vehicle Loadings

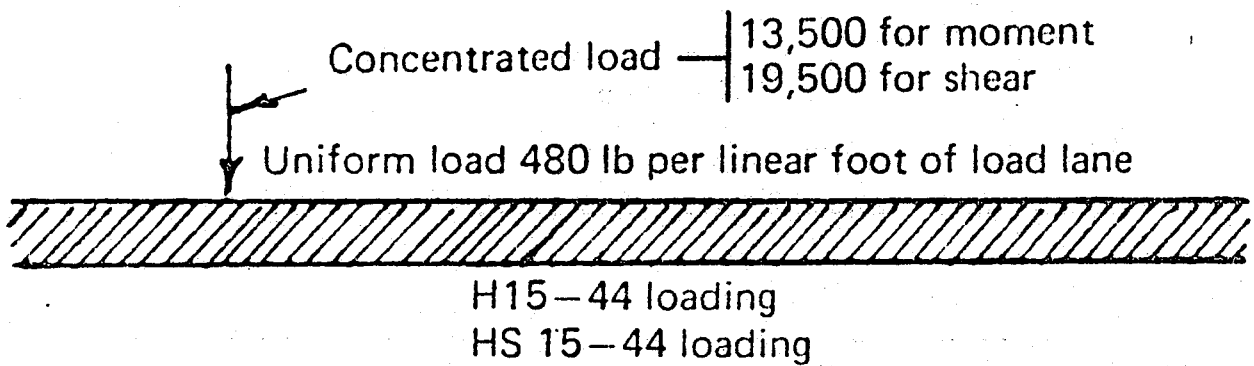
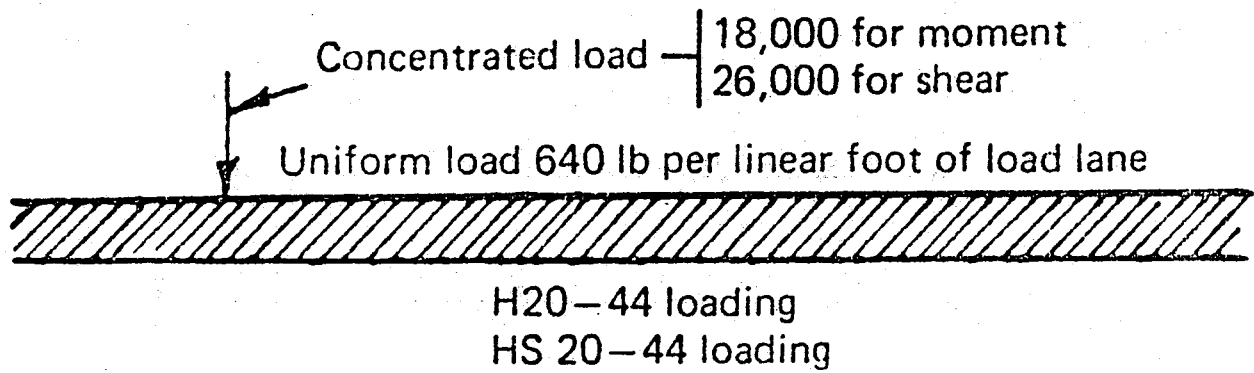
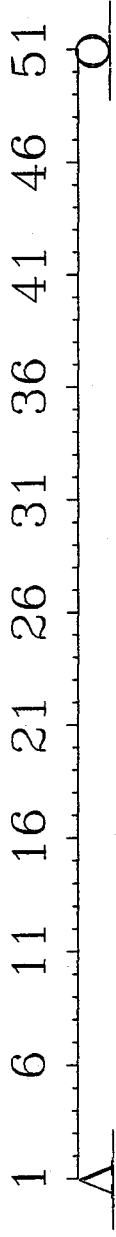
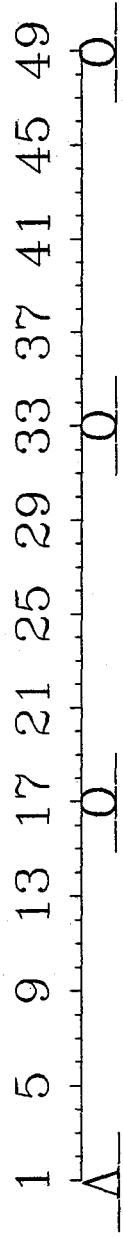


Figure 3. AASHTO Lane Loadings.

and sixteen equal segments for continuous span bridge (see Figure 4). Nodes are introduced at the end of each segment. Each node is assigned three degrees of freedom, two translational and one rotational. The moment and shear at each joint across the span can be found and analyzed.



(a) Simple Span Bridge



(b) Continuous Span Bridge

Figure 4. Bridge Spans.

CHAPTER III
BRIDGE CAPACITY RATING

3.1 Beam/Girder Bridges

3.1.1 Steel Beam/Girder Bridges

- (1). Assumption: The section is compact and the top flange of section is fully supported against lateral movement.
- (2). Input Data:
 - E = modulus of elasticity (ksi).
 - F_y = yield stress (ksi).
 - Z_t = plastic section modulus for top section at each middle span (for positive moment area) (in^3).
 - Z_B = plastic section modulus for bottom section at each middle span (for positive moment area) (in^3)
 - $(Z_B)_N$ = plastic section modulus for bottom section at each support (for negative moment area) (in^3).
 - l_y = lateral unbraced length in compression section (bottom) of beam/girder (for negative moment area) (in).
 - b = flange width in compression section (bottom) of beam/girder (for negative moment. area) (in).

d = depth of beam/girder (in).

t_w = web thickness of beam/girder (in).

r_y = radius of gyration with respect to y-y (transverse) axis (in).

(3). Rating for Bending Moment

a. Positive Moment Resistance

$$M_u (\text{kip-ft}) = (1/12) F_y (Z_B \text{ or } Z_T, \text{ smaller}) \quad (1)$$

b. Negative Moment Resistance

$$\lambda_c = \text{SLENDERNESS PARAMETER} = \frac{KL_y}{r_y} \sqrt{\frac{F_y}{\pi^2 E}} \quad (2)$$

Assume that $K = 1$ in Eq. (2).

$$F_{cr} = \left\{ 0.685^{[Q(\lambda_c)^2]} \right\} Q F_y, \quad \text{for } \lambda_c \sqrt{Q} > 1.5 \quad (3)$$

$$F_{cr} = \left\{ \frac{0.877}{(\lambda_c)^2} \right\} F_y, \quad \text{for } \lambda_c \sqrt{Q} > 1.5 \quad (4)$$

in which Q = reduction factor = 1 for rolled I-sections. The Eqs. (3) and (4) are changed to:

$$F_{cr} = \left\{ 0.685^{[(\lambda_c)^2]} \right\} F_y, \quad \text{for } \lambda_c \leq 1.5 \quad (5)$$

$$F_{cr} = \left\{ \frac{0.877}{(\lambda_c)^2} \right\} F_y, \quad \text{for } \lambda_c > 1.5 \quad (6)$$

$$M_u(\text{kip-ft}) = \left(\frac{1}{12} \right) F_{cr}(Z_B)_N \quad (7)$$

c. Rating Factor

$$RF = \frac{\Phi M_u - \gamma_D M_D}{\lambda_L M_L (1 + I)} \quad (8)$$

in which M_u = resistance moment (kip-ft),

M_D = dead load moment (kip-ft),

M_L = live load moment (kip-ft),

Φ = resistance factor,

γ_D = dead load factor,

γ_L = live load factor, and

I = impact factor.

(4). Rating for End Shear

$$RF = \frac{\Phi V_u - \gamma_D V_D}{\gamma_L V_L (1 + I)}$$

in which V_L = shear resistance (kip) = $0.6F_y d t_w$,

V_D = dead load shear (kip), and,

V_L = live load shear (kip).

Φ , γ_D , γ_L , and I have been defined in the above

section. 3.1.2 Reinforced Concrete Beam/Girder Bridges

(1). Rating for Positive Moment

a. Rectangular Cross Section

(a). Input Data

b = the width of section (in).

d = the distance from the center of reinforcement to the top of section (in).

A_s = the cross section area of reinforcement (in).

f'_c = the ultimate strength of concrete (ksi).

f_y = the yield strength of reinforcement (ksi).

A_s , b , and d are shown in Figure 5(a).

(b). Moment Resistance

$$a = \frac{A_s f_y}{0.85 f'_c b} \quad (10)$$

$$M_u (\text{kip} - \text{ft}) = \frac{A_s f_y \left(d - \frac{a}{2} \right)}{12.0} \quad (11)$$

b. T-Section

(a). Input Data

b_f = the width of flange (in).

b_w = the width of web (in).

h_f = the thickness of flange (in).

A_s , d , f'_c , and f_y have been defined in the above section. A_s , b_f , b_w , d and

h_f are shown in Figure 5 (b).

(b). Moment Resistance

$$a = \frac{A_s f_y}{0.85 f'_c b_f} \quad (12)$$

if $a \leq h_f$, then

$$M_u (\text{kip} - \text{ft}) = \frac{A_s f_y \left(d - \frac{a}{2} \right)}{12.0} \quad (13)$$

if $a > h_f$, then

$$A_{sf} = \frac{0.85 f'_c (b_f - b_w) h_f}{f_y} \quad (14)$$

$$a = \frac{(A_s - A_{sf}) f}{0.85 f'_c b_w} \quad (15)$$

$$M_u (\text{kip} - \text{ft}) = \frac{(A_s - A_{sf}) f_y \left(d - \frac{a}{2} \right) + A_{sf} f_y \left(d - \frac{h_f}{2} \right)}{12.0}$$

(2). Rating for Negative Moment

a. Rectangular Section

(a). Input Data

b = the width of section (in).

d' = the distance from the center of reinforcement to the bottom of section (in).

A_s' = the cross section area of reinforcement (in^2).

f'_c and f_y have been defined in the above section.

A_s' , b , and d' are shown in Figure 6 (a).

(b). Moment Resistance

$$a = \frac{A'_s f_y}{0.85 f'_c b} \quad (17)$$

$$M_u (\text{kip} - \text{ft}) = \frac{A'_s f_y \left(d' - \frac{a}{2} \right)}{12.0} \quad (18)$$

b. T-section

(a). Input Data

b_w = the width of web (in).

h_f = the thickness of flange (in).

A'_s , d' , f'_c , and f_y have been defined in the above section. A'_s ,

b_w , d' , and h_f are shown in Figure 6 (b).

(b). Moment Resistance

$$a = \frac{A'_s f_y}{0.85 f'_c b_w} \quad (19)$$

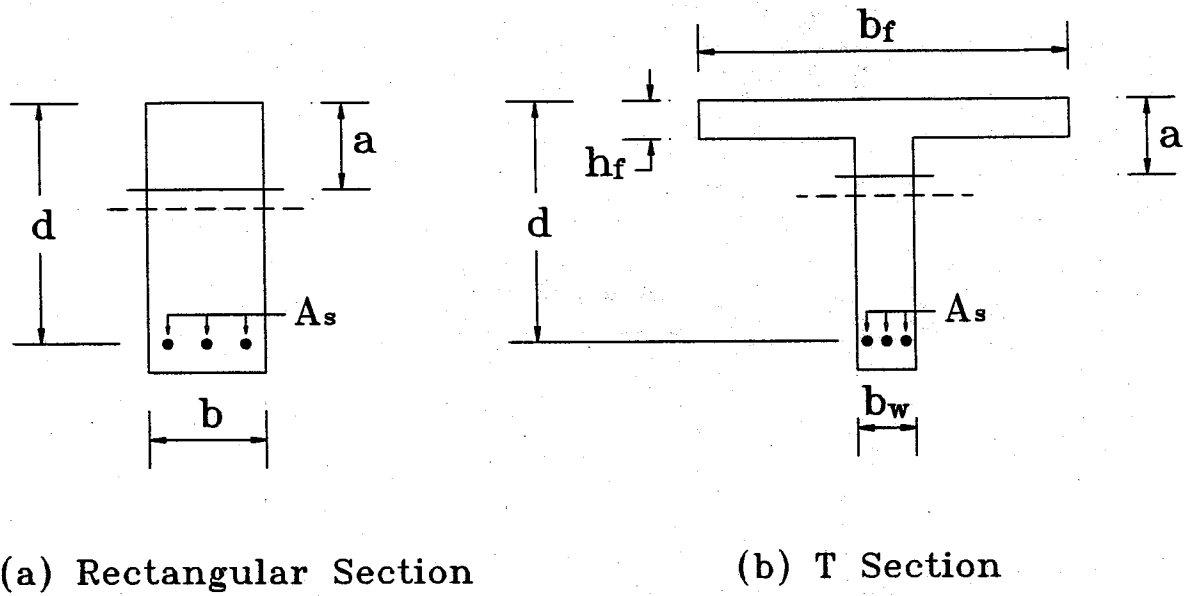


Figure 5. Typical Cross Sections of Reinforced Concrete Beam/Girder Bridges for Positive Moments

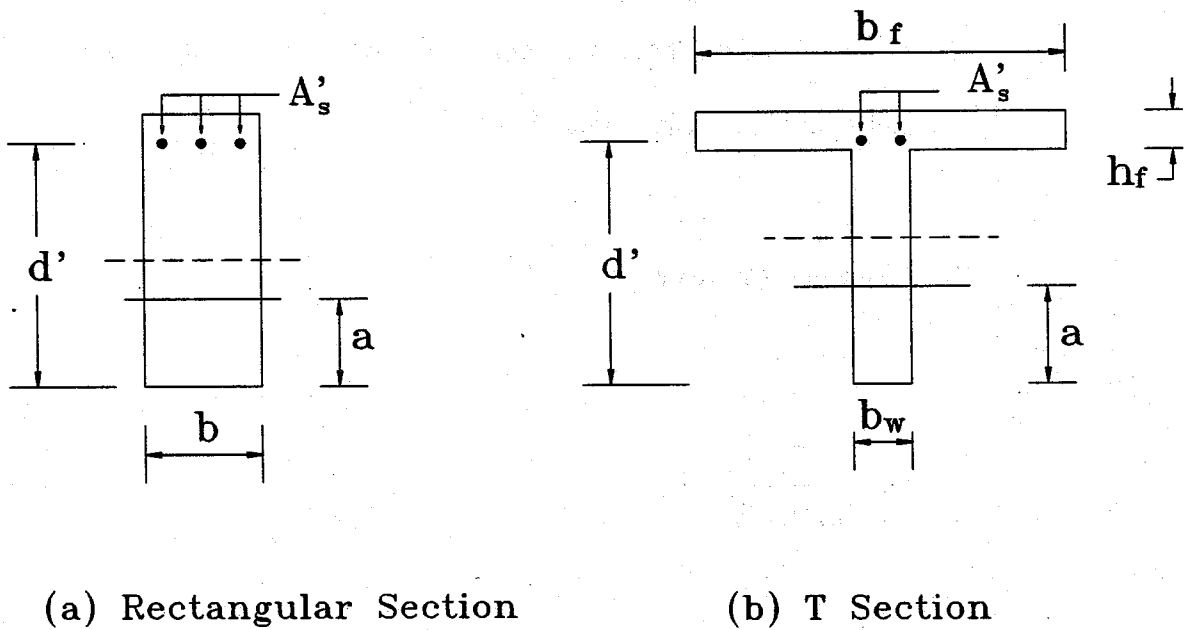


Figure 6. Typical Cross Sections of Reinforced Concrete Beam/Girder bridge for Negative Moments

$$M_u (\text{kip-ft}) = \frac{A'_s f_y \left(d' - \frac{a}{2} \right)}{12.0} \quad (20)$$

(3). Rating Factor

The equation of rating factor is shown in Eq. (8).

3.1.3 Timber Beam/Girder Bridges (Simple Bridges Only)

(1). Input Data

f_b = allowable bending stress (ksi).

S_T = section modulus for top section (in^3).

S_B = section modulus for bottom section (in).

(2). Moment Resistance

$$M_u (\text{kip-ft}) = \left(\frac{1}{12} \right) f_b (S_B \text{ or } S_T, \text{ smaller}) \quad (21)$$

(3). Rating Factor

The equation of rating factor is shown in Eq. (8).

3.2 Longitudinal Concrete Deck/Slab Bridges

3.2.1 Rating for Positive Moment

(1). Input Data

A_s = the cross section area of reinforcement per 1 foot deck/slab (in²/ft).

d , f_c , and f_y have been defined in the section of reinforced concrete beam/girder bridges. A_s and d are shown in Figure 7 (a).

(2). Moment Resistance and Live Load Moment

$$a = \frac{A_s f_y}{0.85 f'_c 12.0} \quad (23)$$

$$M_L = \text{LIVE LOAD MOMENT} = \frac{WHEELLOADMOMENT}{E} \quad (24)$$

in which E = distribution width (ft) = $4 + 0.065 \leq 7'$ and S = effective span length (ft)

3.2.2 Rating for Negative Moment

(1). Input Data

A'_s = the cross section area of reinforcement per 1 foot deck/slab (in 2/ft).

d' , f_c , and f_y have been defined in the section of reinforced concrete beam/girder bridges. A'_s , and d' are shown in Figure 7 (b).

(2). Moment Resistance and Live Load Moment,

$$a = \frac{A'_s f_y}{0.85 f'_c 12.0} \quad (25)$$

$$M_u (\text{kip} - \text{ft}) = \frac{A'_s f_y \left(d' - \frac{a}{2} \right)}{12.0} \quad (26)$$

The live load moment (M_L) has been defined in Eq. (24).

3.2.3 Rating Factor

The Eq. (8) will be used to obtain the rating factor.

3.3 Transverse Deck/Slab Bridges

3.3.1 Reinforced Concrete Transverse Deck/Slab Bridges

(1). Simple Span (Two Longitudinal Stringers)

a. Input Data

S_g = center-to-center stringer spacing (in).

b = the flange width of the stringer (in).

h_d = the thickness of the deck/slab (in).

A_s = the cross section area of reinforcement per 1 foot deck/slab (in^2/ft).

WD = the distributed dead load for 1 foot deck/slab cross section (kip/ft).

d , f_c , and f_y , have been defined in the section of reinforced concrete beam/girder bridges. A_s and d are shown in Figure 7 (a).

b. Moment Resistance, Dead Load Moment, and Live Load Moment

The values of a and M_u can be calculated from Eqs. (22) and (23).

$$S(ft) = \text{EFFECTIVE SPAN LENGTH} \leq \frac{s_g - b + h_d}{12.0} \leq S_g \quad (27)$$

$$M_D(kip - ft) = \frac{w_D S^2}{8} \quad (28)$$

$$M_L(kip - ft) = \frac{S + 2}{32} P_{\max} \quad (29)$$

in which P_{\max} , = the maximum wheel load of the vehicle.

(2). Continuous Span (Three or More Longitudinal Stringers)

a. Input Data

h_s = the depth of the stringer (in).

S_g , b , h_d , A_s , w_D , d , f_c , and f_y , have been defined in the above section. A_s and d are shown in Figure 7 (a).

b. Moment Resistance, Dead Load Moment, and Live Load Moment

The values of a and M_u can be calculated from Eqs. (22) and (23).

$$S_c(ft) = \frac{S_g - b}{12.0}, \text{ FOR REINFORCED CONCRETE STRINGERS} \quad (30)$$

$$S_c(ft) = \frac{S_g - \frac{1}{2}b}{12.0}, \text{ FOR STEEL STRINGERS} \quad (31)$$

$$S_c(ft) = \frac{S_g - b + \frac{1}{2}h_s}{12.0}, \text{ FOR TIMBER STRINGERS} \quad (32)$$

$$M_D(kip-ft) = 0.8 \left(\frac{1}{8} w_D S_c^2 \right) = \frac{w_D S_c^2}{10} \quad (33)$$

$$M_L(kip-ft) = 0.8 \left(\frac{S_c + 2}{32} \right) P_{\max} \quad (34)$$

in which P_{\max} = the maximum wheel load of the vehicle.

(3). Rating Factor

The Eq. (8) will be used to obtain the rating factor.

3.3.2 Timber Transverse Deck/Slab Bridges

(1). Input Data

f_b = the allowable bending stress (ksi).

S = the section modulus of cross section (in^3).

S_g , b , w_D , and h_d have been defined in the section of reinforced concrete deck/slab.

(2). Moment Resistance

$$M_u(\text{kip} - \text{ft}) = \frac{f_b S}{12.0} \quad (35)$$

(3). Dead Load and Live Load Moments for Simple Span (Two Longitudinal Stringers)

$$S_c(\text{ft}) = \frac{S_g - \frac{1}{2}b}{12.0} \leq \frac{S_g - b + h_d}{12.0} \quad (36)$$

$$M_D(\text{kip} - \text{ft}) = \frac{w_D S_c^2}{8} \quad (37)$$

$$M_L(\text{kip} - \text{ft}) = \frac{P_{\max}}{4} \left(S_c - \frac{T}{12.0} \right) \quad (38)$$

in which P_{\max} = the maximum wheel load of vehicle (kip),

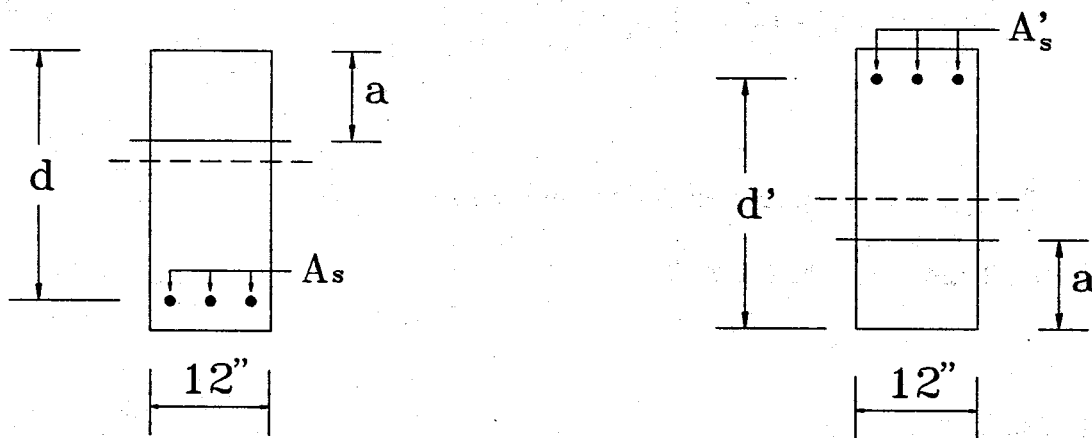
$T = 15$ in, for H15, HS 15, and Type 3 Trucks, and

$T = 20$ in, for H20, HS20, Type 3S2, and Type 3-3 trucks.

S_c and T are shown in Figure 8.

(4). Dead Load and Live Load Moments for Continuous Span (Three or More Longitudinal Stringers)

$$M_D(\text{kip} - \text{ft}) = 0.8 \left(\frac{1}{8} w_D S_c^2 \right) = \frac{w_D S_c^2}{10}$$



(a) Positive Moment

(b) Negative Moment

Figure 7. Typical Cross Sections of Reinforced Concrete Transverse Deck/Slab Bridge

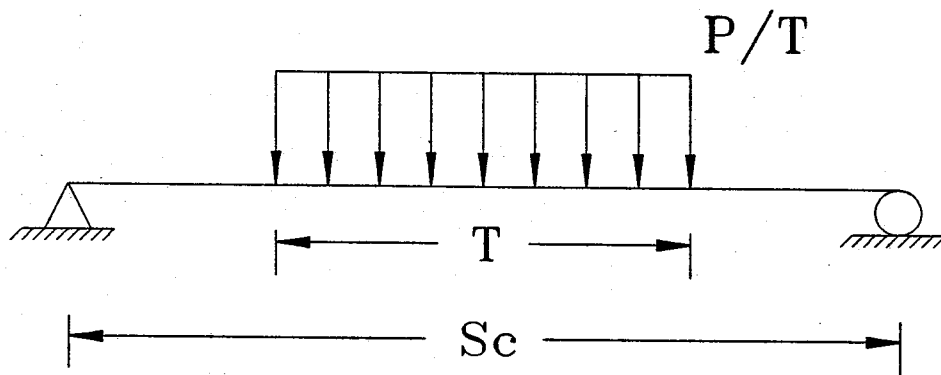


Figure 8. Wheel Load Distribution of Timber Transverse Deck/Slab Bridge

$$M_L(kip - ft) = 0.8 \left(\frac{P_{\max}}{4} \right) \left(S_c - \frac{T}{12.0} \right) \quad (40)$$

S_c , T , P_{\max} , and w_D have been defined in the above section.

S_c and T are shown in Figure 8.

(5). Rating Factor

The Eq. (8) will be used to obtain the rating factor.

CHAPTER IV

FATIGUE LIFE ANALYSIS

The fatigue life of a member depends upon its stress range (i.e., the algebraic difference - between the, maximum and minimum stress), number of cycles and the method of connection, as demonstrated by Fisher [1]. The design stress range can be calculated from the stress history, caused by the passage of a single vehicle model across the bridge. It must also include the effect of impact and load distribution on the bridges.

The fatigue life will be determined by using the method suggested by Schilling and Klippstein [9]. This method is an extension of Fisher's research [1]. According to the method, N , the number of cycles to fatigue failure is related to the equivalent stress range, S_c (ksi), by the following equation:

$$N = A / (S_c)^m \quad (41)$$

where m is the slope of SN curve, $m = 3$ is used in the suggested design method, and A is a constant whose values for the various AASHTO categories are listed in the Table 1 (Schilling and Klippstein 1978). The design SN curves that were defined by the above equation and Table 1 are shown in Figure 9.

Based on the cumulative damage law of Miner's theory [8], the equivalent stress range S_c becomes

Table 1. The Values of Constant A in SN Curves for the Various AASHTO Categories.

| Category | S_L^* (ksi) | Constant A |
|------------------------|---------------|-------------------|
| A | 12.0 | 240×10^8 |
| B | 8.0 | 105×10^8 |
| C (Stiffeners) | 6.0 | 37×10^8 |
| C' (Other Attachments) | 5.0 | 37×10^8 |
| D | 3.5 | 20×10^8 |
| E | 2.5 | 10×10^8 |
| F | 4.0 | 10×10^8 |

Note: S_L^* = the maximum allowable stress range for infinite fatigue life.

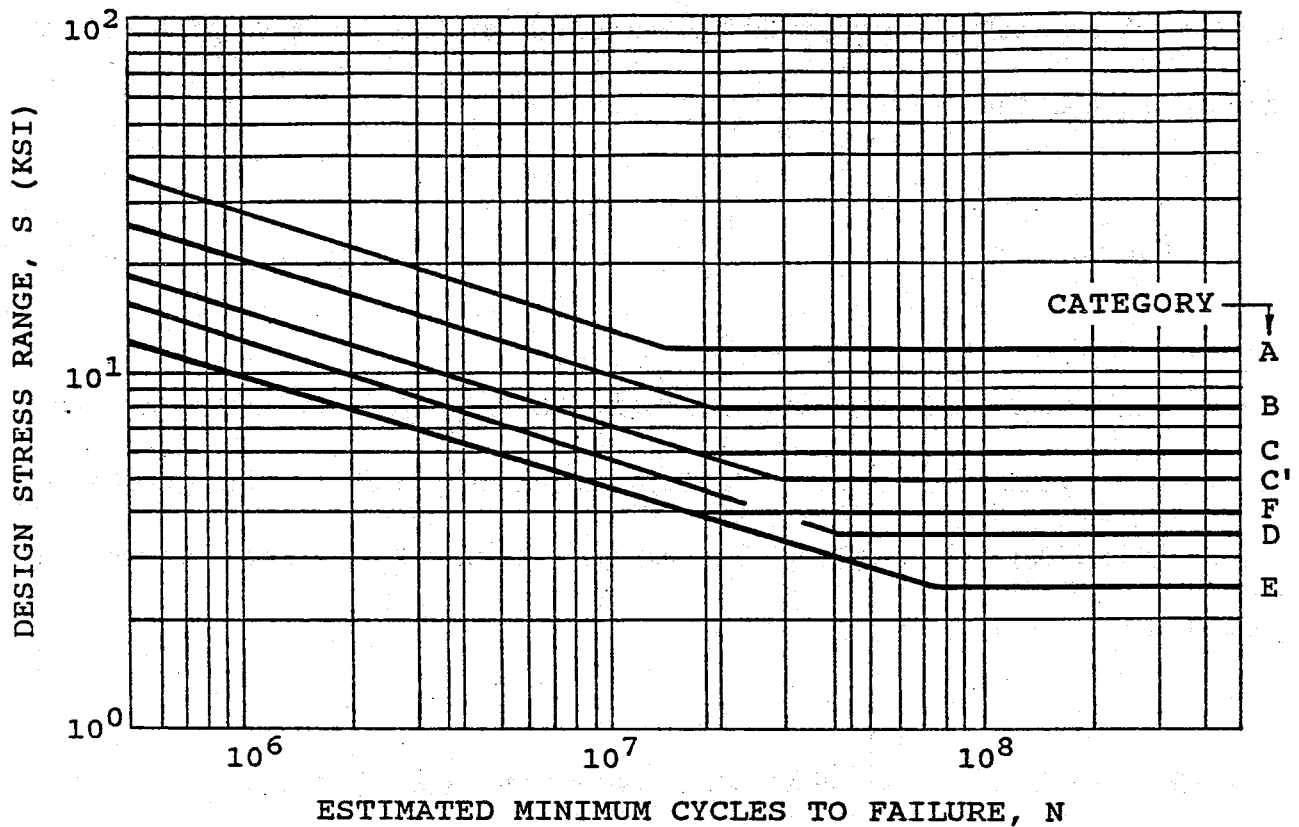


Figure 9. Design SN Curves.

$$S_e = \left[\sum_{i=1}^n \alpha_i (S_i)^m \right]^{\frac{1}{m}} \quad (42)$$

where α_i = the fraction of stress range S_i

$$\alpha_i = \frac{\text{the number of cycles for stress range } S_i}{\text{the total number of cycles for stress-time history}}$$

Finally, the predicted fatigue life in years, L_f , can be calculated from

$$L_f = N / [(365) (T) (P)] \quad (43)$$

in which T is the average daily truck traffic (ADTT); and P is the number of loading cycles per truck passage.

CHAPTER V

EXAMPLES

5.1 Transverse Reinforced Concrete Deck

The transverse reinforced concrete deck is shown in Figure 10 [4].

Preparation of the Input Data File:

Control Information

DC 1 : THE TRANSVERSE REINFORCED CONCRETE DECK

DC 2 : 3,1,0,2

DC 3 : 3,4

DC 4 : 2,0,1,1,1,0,1,1000.

For Transverse deck

DC 1 : 1

DC 2.1.1 : 2,3.25,60.0

DC 2.1.2 : 84.,15.,7.5,5.19,0.62

DC 2.1.3: 1,51.

The Input Data File Is Printed Out As:

THE TRANSVERSE REINFORCED CONCRETE DECK

3,1,0,2

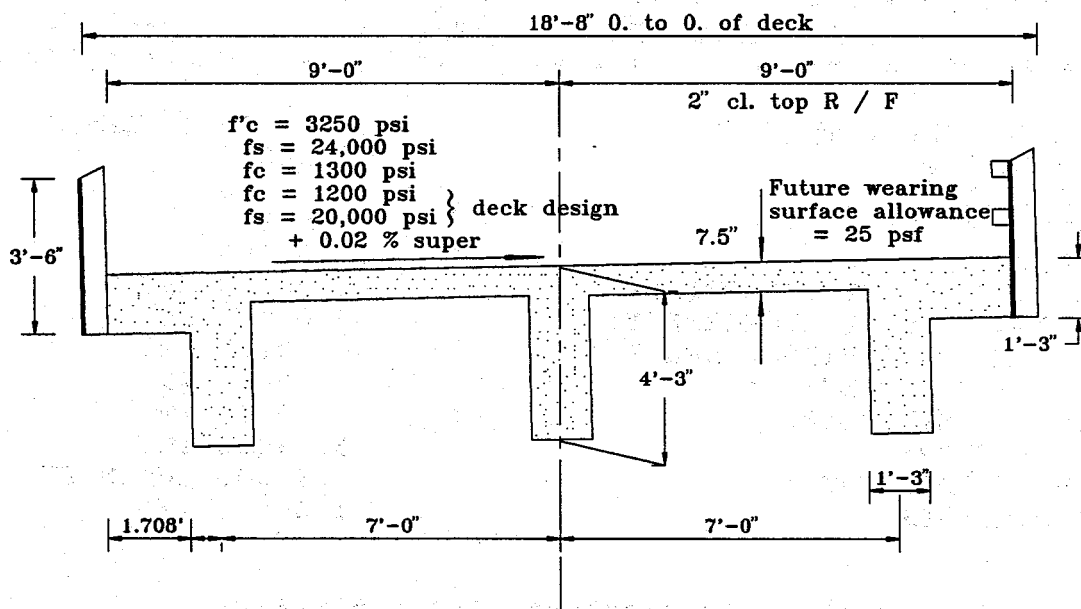


Figure 10. Roadway section: T-beam bridge.

3,4 2,0,1,1,1,0,1,1000.0

1

2,3.25,60.0 84.0,15.0,7.5,5.19,0.62

1,51.0

The Output Result File Is Given As:

THE TRANSVERSE REINFORCED CONCRETE DECK

***** NO. 1 RATING VEHICLE: TYPE 3-3 *****

| | |
|-------------------------------------|-----------------------|
| AVERAGE DAILY TRUCK TRAFFIC: | 1000.00000 TRUCKS/DAY |
| DEAD LOAD FACTOR: | 1.20000 |
| LIVE LOAD FACTOR: | 1.45000 |
| RESISTANCE FACTOR: | .65000 |
| IMPACT FACTOR: | .20000 |
| ULTIMATE STRENGTH OF CONCRETE: | 3.25000 KSI |
| YIELD STRENGTH OF REINFORCEMENT: | 60.00000 KSI |
| CENTER TO CENTER STRINGER SPACING:! | 84.00000 IN |
| FLANGE WIDTH OF STRINGER: | 15.00000 IN |
| THICKNESS OF DECK/SLAB: | 7.50000 IN |
| DEPTH OF SECTION: | 5.19000 IN |
| AREA OF REINFORCEMENT: | .62000 IN*IN/FT |
| DEPTH OF STRINGER: | 51.00000 IN |

NO. 2 RATING VEHICLE: HS20-44

AVERAGE DAILY TRUCK TRAFFIC:

1000.00000 TRUCKS/DAY

THE RATING RESULT FOR TRANSVERSE DECK/SLAB BRIDGE

POSITIVE MOMENT

RATING VEHICLE

RATING FACTOR

HS20-44

1.63

5.2 Transverse Treated Timber Deck

The sample problem for a Treated Timber Deck is the rating of a continuous 2 " x 4 " laminated timber deck supported by 6 " x 2 0 " timber stringers, shown in Figure 11 [6]. The stringer spacing is 2'-2". The rating load is one 12 kip wheel of an H-15 truck for which the bridge was originally designed.

Preparation of the Input Data File:

Control Information

DC 1 : Continuous Transverse Laminated Timber Deck
DC 2 : 3, 1, 3, 1
DC 3 : 7
DC 4 : 2, 1, 1, 1, 1, 0, 1, 1 0 0 0.

For Transverse deck

DC 1 : 2
DC 2.2.1: 2, 2.394
DC 2.2.2: 26., 6., 4., 30.

The Input Data File Is Printed Out As:

Continuous Transverse Laminated Timber Deck

3,1,3,1

7

2,1,1,1,1,0,1,1000.

2

2,2.394

26.,6.,4.,30.

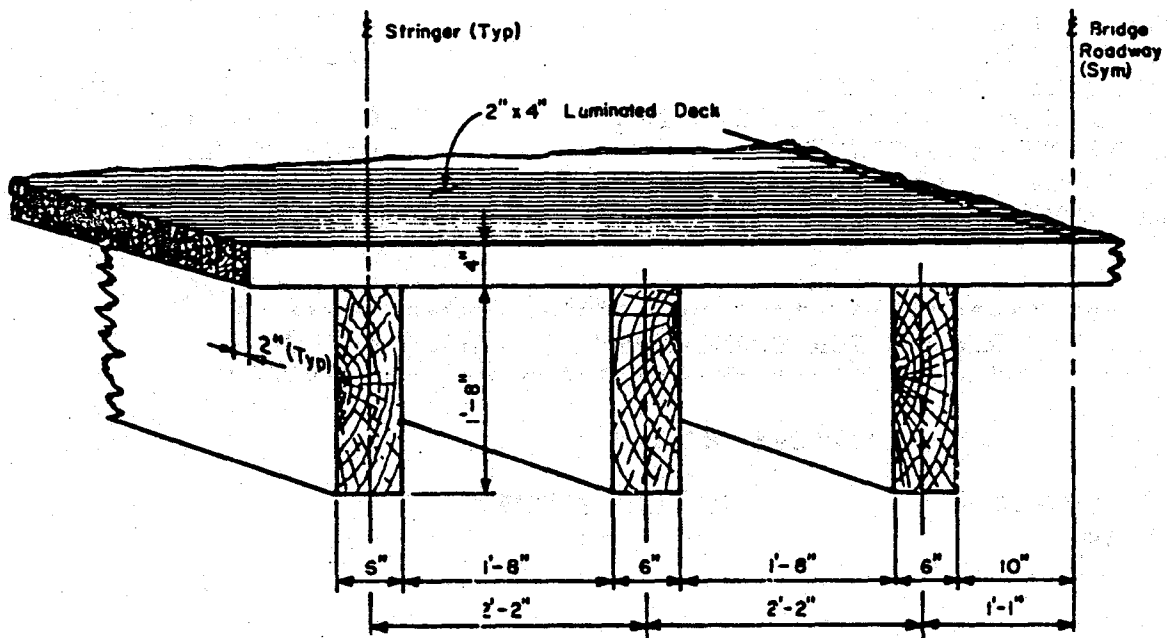


Figure 11. Transverse Section of Treated Timber Deck.

The Output Result File Is Given As:

Continuous Transverse Laminated Timber Deck

***** NO. 1 RATING VEHICLE: H15-44 *****

| | |
|------------------------------------|-----------------------|
| AVERAGE DAILY TRUCK TRAFFIC: | 1000.00000 TRUCKS/DAY |
| DEAD LOAD FACTOR: | 1.20000 |
| LIVE LOAD FACTOR: | 1.45000 |
| RESISTANCE FACTOR: | .75000 |
| IMPACT FACTOR: | .20000 |
| ALLOWABLE BENDING STRESS: | 2.39400 KSI |
| CENTER TO CENTER STRINGER SPACING: | 26.00000 IN |
| FLANGE WIDTH OF STRINGER: | 6.00000 IN |
| THICKNESS OF DECK/SLAB: | 4.00000 IN |
| SECTION MODULUS: | 30.00000 IN*IN*IN |

THE RATING RESULT FOR TRANSVERSE DECK/SLAB BRIDGE

POSITIVE MOMENT

| RATING VEHICLE | RATING FACTOR |
|----------------|---------------|
| H15-44 | .83 |

5.3 Longitudinally Reinforced Concrete Slab

The bridge shown in elevation and plan in Figure 12 is also shown in section in Figure 13 [4]. The superstructure for this bridge is designed as a longitudinally reinforced slab by service load design procedures.

The allowable stress for design are

$$f'_c = 4000 \text{ psi}$$

$$f_c = 1600 \text{ psi}$$

$$f_y = 60,000 \text{ psi}$$

$$f_s = 24,000 \text{ psi}$$

Preparation of the Input Data File:

Control Information

DC 1 : Three-Span Continuous Concrete Longitudinal Slab Bridge

DC 2 : 2,1,3,2

DC 3 : 4,3

DC 4 : 2,1,0,1,1,0,1,2000.

For Longitudinal Reinforced Concrete deck

DC 1 : 2,0.331

DC 2 : 7.

DC 3.2.1 : 3,3605.

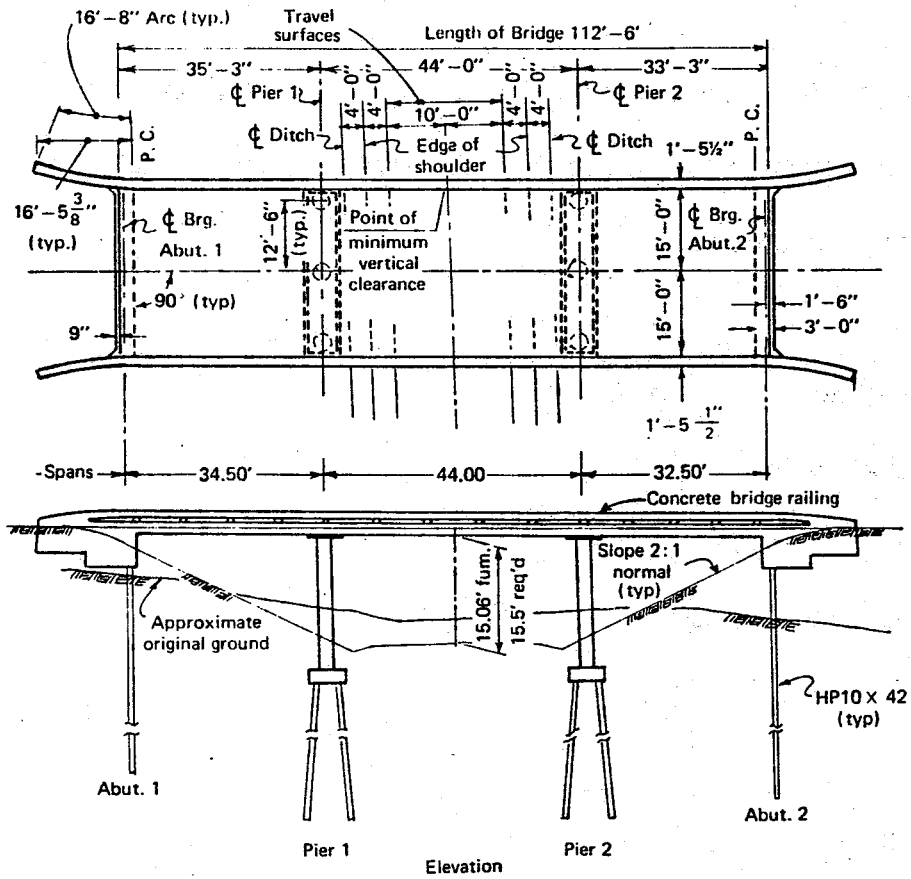


Figure 12. Longitudinally Reinforced Slab Bridge: Plan and Elevation.

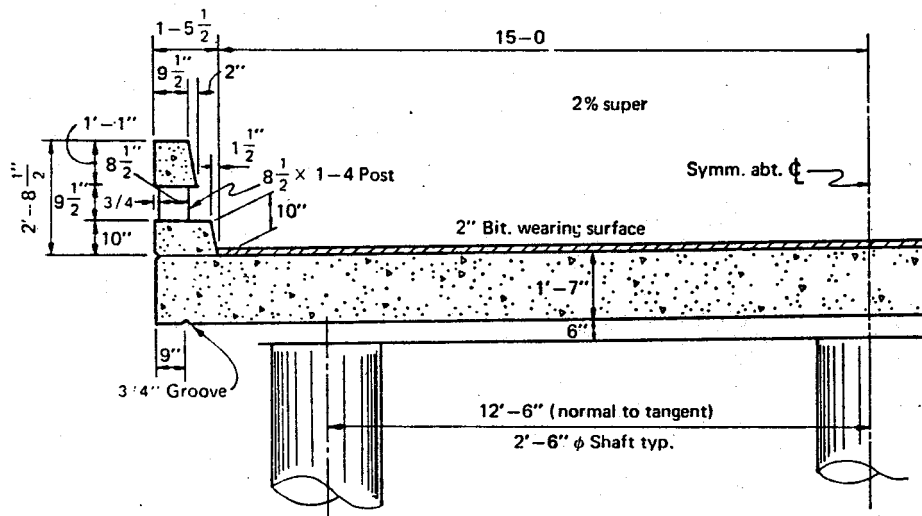


Figure 13. Typical Section: Longitudinally Reinforced Slab Bridge.

DC 3.2.2 : 2.156,3589.,9348.
2:156,3589.,9348:
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589. 9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589.:9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.156,3589.,9348.
2.75,3589.:9348.
2.75,3589.,9348.
2:75,3589.,9348.
2.75,3589.,9348.
2.75,3589.:9348.
2.75,3589.:9348.
2.75,3589.,9348.
2.75,3589.:9348.

2.75,3589.,9348.

2.75,3589.,9348.

2.75,3589.,9348.

2:75,3589.,9348.

2.75,3589.,9348.

2.75,3589:.,9348.

2.75,3589.,9348.

2.75,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2:156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

DC 4 : 4.,60.

DC 5.2.1 : 17.,17.,17.

DC 5.2.2 : 16.36,16.36

DC 5.2.3 : 1.35,1.35,1.35

DC 5.2.4 : 2.18,2.18

The Input Data File Is Printed Out As:

Three-Span: Continuous Concrete Longitudinal Slab Bridge

2,1,3,2

4,3 2,1,0,1,1,0,1,2000.

2,0.331

7. 3,3605.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.156,3589.,9348.

2.75,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 2.156,3589.,9348.
 4.,60.
 17.,17.,17.
 16.36,16.36
 1.35,1.35,1.35
 2.18,2.18

The Output Result File Is Given As:

Three-Span Continuous Concrete Longitudinal Slab Bridge

```

* *****          NO. 1 RATING VEHICLE: HS20-44          *****
AVERAGE DAILY TRUCK TRAFFIC:                2000.00000 TRUCKS/DAY
DEAD LOAD FACTOR:                            1.20000
LIVE LOAD FACTOR:                            1.45000
RESISTANCE FACTOR:                          .85000
IMPACT FACTOR:                               .20000
DEAD LOAD OF BRIDGE:                         .33100 K/FT
DISTRIBUTION WIDTH:                          7.00000' FT
MODULUS OF ELASTICITY OF BRIDGE:            3605.00000 KSI
ULTIMATE STRENGTH OF CONCRETE:              4.00000 KSI
YIELD STRENGTH OF REINFORCEMENT:            60.00000 KSI
  
```

| SPAN | DEPTH (IN) | AREA OF REINFORCEMENT (IN*IN/FT) |
|---------|---------------|-------------------------------------|
| 1 | 17.00000 | 1.35000 |
| 2 | 17.00000 | 1.35000 |
| 3 | 17.00000 | 1.35000 |
| SUPPORT | DEPTH (IN) | AREA OF REINFORCEMENT (IN*IN/FT) |

| ELE. | LENGTH (FT) | CROSS AREA (IN*IN) | MOMENT OF INERTIA (IN*IN*IN*IN) |
|------|----------------|-----------------------|------------------------------------|
| 2 | 16.36000 | 2.18000 | |
| 3 | 16.36000 | 2.18000 | |
| 1 | 2.15600 | 3589.00000 | 9348.00000 |
| 2 | 2.15600 | 3589.00000 | 9348.00000 |
| 3 | 2.15600 | 3589.00000 | 9348.00000 |
| 4 | 2.15600 | 3589.00000 | 9348.00000 |
| 5 | 2.15600 | 3589.00000 | 9348.00000 |
| 6 | 2.15600 | 3589.00000 | 9348.00000 |
| 7 | 2.15600 | 3589.00000 | 9348.00000 |
| 8 | 2.15600 | 3589.00000 | 9348.00000 |
| 9 | 2.15600 | 3589.00000 | 9348.00000 |
| 10 | 2.15600 | 3589.00000 | 9348.00000 |
| 11 | 2.15600 | 3589.00000 | 9348.00000 |
| 12 | 2.15600 | 3589.00000 | 9348.00000 |
| 13 | 2.15600 | 3589.00000 | 9348.00000 |
| 14 | 2.15600 | 3589.00000 | 9348.00000 |
| 15 | 2.15600 | 3589.00000 | 9348.00000 |
| 16 | 2.15600 | 3589.00000 | 9348.00000 |
| 17 | 2.75000 | 3589.00000 | 9348.00000 |
| 18 | 2.75000 | 3589.00000 | 9348.00000 |
| 19 | 2.75000 | 3589.00000 | 9348.00000 |
| 20 | 2.75000 | 3589.00000 | 9348.00000 |
| 21 | 2.75000 | 3589.00000 | 9348.00000 |
| 22 | 2.75000 | 3589.00000 | 9348.00000 |
| 23 | 2.75000 | 3589.00000 | 9348.00000 |
| 24 | 2.75000 | 3589.00000 | 9348.00000 |
| 25 | 2.75000 | 3589.00000 | 9348.00000 |
| 26 | 2.75000 | 3589.00000 | 9348.00000 |
| 27 | 2.75000 | 3589.00000 | 9348.00000 |
| 28 | 2.75000 | 3589.00000 | 9348.00000 |
| 29 | 2.75000 | 3589.00000 | 9348.00000 |
| 30 | 2.75000 | 3589.00000 | 9348.00000 |
| 31 | 2.75000 | 3589.00000 | 9348.00000 |
| 32 | 2.75000 | 3589.00000 | 9348.00000 |
| 33 | 2.15600 | 3589.00000 | 9348.00000 |
| 34 | 2.15600 | 3589.00000 | 9348.00000 |
| 35 | 2.15600 | 3589.00000 | 9348.00000 |
| 36 | 2.15600 | 3589.00000 | 9348.00000 |
| 37 | 2.15600 | 3589.00000 | 9348.00000 |
| 38 | 2.15600 | 3589.00000 | 9348.00000 |
| 39 | 2.15600 | 3589.00000 | 9348.00000 |
| 40 | 2.15600 | 3589.00000 | 9348.00000 |
| 41 | 2.15600 | 3589.00000 | 9348.00000 |
| 42 | 2.15600 | 3589.00000 | 9348.00000 |
| 43 | 2.15600 | 3589.00000 | 9348.00000 |
| 44 | 2.15600 | 3589.00000 | 9348.00000 |
| 45 | 2.15600 | 3589.00000 | 9348.00000 |
| 46 | 2.15600 | 3589.00000 | 9348.00000 |
| 47 | 2.15600 | 3589.00000 | 9348.00000 |
| 48 | 2.15600 | 3589.00000 | 9348.00000 |

THE RATING RESULT FOR CONTINUOUS SPAN LONGITUDINAL DECK/ SLAB
BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | HS20-44 | 8.19 |
| 2 | HS20-44 | 8.87 |
| 3 | HS20-44 | -.84 |

NEGATIVE MOMENT

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 2 | HS20-44 | 2.09 |
| 3 | HS20-44 | 2.09 |

***** NO. 2 RATING VEHICLE: TYPE 3-3 *****
 AVERAGE DAILY TRUCK TRAFFIC: 2000.00000 TRUCKS/DAY

THE RATING: RESULT FOR CONTINUOUS SPAN LONGITUDINAL DECK/SLAB
BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | TYPE 3-3 | **** |
| 2 | TYPE 3-3 | **** |
| 3 | TYPE 3-3 | **** |

NEGATIVE MOMENT

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 2 | TYPE 3-3 | 2.26 |
| 3 | TYPE 3-3 | 2.26 |

5.4 Timber Girder Bridge

The sample problem is the rating of 6" x 20" timber stringers which support a continuous 2"x4" laminated timber deck, shown in Figure 11 [6]. The stringer spacing is 2'-2". The rating load is one 12 kip wheel of an H-15 truck for which the bridge was originally designed.

Preparation of the Input Data File:

Control Information

DC 1 : Timber beam bridge, 23 feet long, simply supported

DC 2 : 1,1,3,1

DC 3 : 5

DC 4 : 2,1,1,1,1,1,1,1000.

For Beam/Girder Bridge. Timber

DC 1 : 1,0.078

DC 2 : 3,0.542,0.542

DC 3.1.1 : 23

DC 4.3.1 : 2.394

DC 4.3.1.1 : 400.

The Input Data File Is Printed Out As:

Timber beam bridge, 23 feet long, simply supported

1,1,3,1

5

2,6*1,1000.

1,0.078

3,0.542,0.542

23

2.394

400.

The Output Result File Is Given As:

Timber beam bridge, 23 feet long, simply supported

***** NO. 1 RATING VEHICLE HS15-44 *****

AVERAGE DAILY TRUCK TRAFFIC: 1000.00000 TRUCKS/DAY

DEAD LOAD FACTOR: 1.00000

LIVE LOAD FACTOR: 1.45000

RESISTANCE FACTOR: .75000

IMPACT FACTOR: .20000

DEAD LOAD OF BRIDGE: .07800 K/FT

DISTRIBUTION FACTOR FOR BENDING MOMENT: .54200

DISTRIBUTION FACTOR FOR SHEAR: .54200

BRIDGE LENGTH: 23.00000 FT

ALLOWABLE BENDING STRESS: 2.39400 KSI

SEC. MOD. AT THE MAX. POS. MOMENT PT. 1: 400.00000 IN*IN*IN *

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
|------|----------------|---------------|

| | | |
|---|---------|-----|
| 1 | HS15-44 | .84 |
|---|---------|-----|

5.5 50-FT Simple Span Concrete Girder

The structure is a concrete deck girder bridge with 50 ft simple spans. The girder spacing is 5 ft 6 in with a 29 ft roadway. The cross section is shown in Figure 14 [6]. The input data and rating results are given as below.

Preparation of the Input Data File:

Control Information

DC 1 : 50-FT SIMPLE SPAN CONCRETE GIRDERS DC 2 : 1,1,3,2

DC 3 : 3,4

DC 4 : 2,0,1,1,1,0,1,500.0 For Beam/Girder Brides

DC 1 : 1,1.0

DC 2 : 2,0.917,0.917

DC 3.1.1 : 50.0

DC 4.2 : 2,3.0,40.0

DC 4.2.1.2: 66.0,12.0,5.75,29.4,17.16

The Input Data File Is Printed Out As:

50-FT SIMPLE SPAN CONCRETE GIRDERS

1,1,3,2

3,4

2,0,1,1,1,0,1,500.0

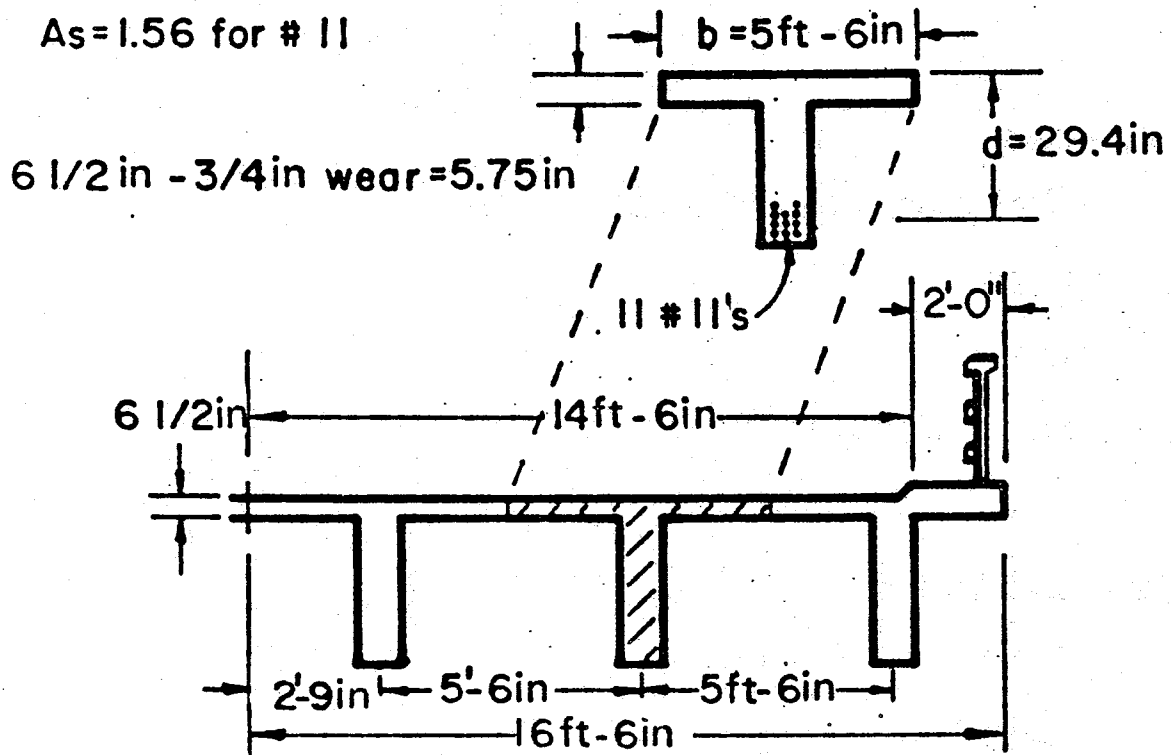


Figure 14. Cross Section of Simple Span Reinforced Concrete Beam Bridge.

1,1.0
 2, 0.917, 0.917
 50.0
 2,3.0,40.0
 66.0,12.0,5.75,29.4,17.16

The Output Result File Is Given As:

50-FT SIMPLE SPAN CONCRETE GIRDERS .

```

*****          NO. 1 RATING VEHICLE: TYPE 3-3          *****
AVERAGE DAILY TRUCK TRAFFIC:          500.00000 TRUCKS/DAY
DEAD LOAD FACTOR:                      1.20000
LIVE LOAD FACTOR:                      1.30000
RESISTANCE FACTOR:                    .65000
IMPACT FACTOR:                         .20000
DEAD LOAD OF BRIDGE:                   1.00000 K/FT
DISTRIBUTION FACTOR FOR BENDING MOMENT: .91700
DISTRIBUTION FACTOR FOR SHEAR:         .91700
BRIDGE LENGTH:                         50.00000 FT
ULTIMATE STRENGTH OF CONCRETE:        3.00000 KSI
YIELD STRENGTH OF REINFORCEMENT:     40.00000 KSI
FLANGE WIDTH OF T-SECTION:            66.00000 IN
WEB WIDTH OF T-SECTION:                12.00000 IN
FLANGE THICKNESS OF T-SECTION:        5.75000 IN
DEPTH OF T-SECTION:                   29.40000 IN
AREA OF REINFORCEMENT:                 17.16000 IN*IN
  
```

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

| POSITIVE MOMENT | | |
|-----------------|----------------|---------------|
| SPAN | RATING VEHICLE | RATING FACTOR |
| 1 | TYPE 3-3 | 2.26 |

NO. 2 RATING VEHICLE: HS20-44

AVERAGE DAILY TRUCK TRAFFIC:

500.00000 TRUCKS /DAY

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | HS20-44 | 1.44 |

5.6 25-FT Simple Span Steel Girder

A simple steel beam bridge with a concrete deck. The span is 25 ft. There are six W24x68 beams spaced at 7 ft 10 in [3]. The input data and rating results are given as below.

Preparation of the Input Data File:

Control Information

DC 1 : SIX W24X68 STEEL GIRDERS, 25-FT SIMPLE SPAN BRIDGE

DC 2 : 1,2,3,2

DC 3 : 3,4

DC 4 : 2,0,1,1,1,0,1,6000.0

For Beam/Girder Bridge

DC 1 : 1,1.5

DC 2 : 1,1.424,1.424

DC 3.1.1 : 25.0

DC 4.1 : 36.0

DC 4.1.1.1: 177.0,177.0,23.73,0.415

For Fatigue Analysis, only for steel bridges

DC 1 : 3

The Input Data File Is Printed Out As:

SIX W24X68 STEEL GIRDERS, 25-FT SIMPLE SPAN BRIDGE

1,2,3,2

3,4

2,0,1,1,1,0,1,6000.0

1,1.5

1,1.424,1.424

25.0

36.0

177.0,177.0,23.73,0.415

3

The Output Result File Is Given As:

SIX W24X68 STEEL GIRDERS, 25-FT SIMPLE SPAN BRIDGE

***** NO. 1 RATING VEHICLE: TYPE 3-3 *****

| | |
|---|----------------------|
| AVERAGE DAILY TRUCK TRAFFIC: | 6000.0000 TRUCKS/DAY |
| DEAD LOAD FACTOR: | 1.20000 |
| LIVE LOAD FACTOR: | 1.45000 |
| RESISTANCE FACTOR: | .65000 |
| IMPACT FACTOR: | .20000 |
| FATIGUE STRESS CATEGORY: | C |
| DEAD LOAD OF BRIDGE: | 1.50000 K/FT |
| DISTRIBUTION FACTOR FOR BENDING MOMENT: | 1.42400 |
| DISTRIBUTION FACTOR FOR SHEAR: | 1.42400 |
| BRIDGE LENGTH: | 25.00000 FT |
| YIELD STRENGTH OF STEEL: | 36.00000 KSI |

SECTION PROPERTIES AT THE MIDDLE SPAN

| | |
|---------------------------------------|--------------------|
| PLASTIC SEC. MODULUS FOR TOP SEC.: | 177.00000 IN*IN*IN |
| PLASTIC SEC. MODULUS FOR BOTTOM SEC.: | 177.00000 IN*IN*IN |
| DEPTH OF SECTION: | 23.73000 IN |
| THICKNESS OF WEB: | .41500 IN |

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | TYPE 3-3 | 1.12 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | TYPE 3-3 | 3.23 |
| 2 | TYPE 3-3 | 3.23 |

THE FATIGUE LIFE FOR SIMPLE SPAN BRIDGE

POSITIVE MOMENT

| SPAN | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|------|-------------------------------|---------------------------------|----------------------|
| 1 | 5.82584 | | 4 INFINITE |

***** NO. 2 RATING VEHICLE: HS20-44 *****

AVERAGE DAILY TRUCK TRAFFIC: 6000.00000 TRUCKS/DAY *

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | HS20-44 | .83 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | HS20-44 | 2.03 |
| 2 | HS20-44 | 2.03 |

THE FATIGUE LIFE FOR SIMPLE SPAN BRIDGE POSITIVE MOMENT

| SPAN | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|------|-------------------------------|---------------------------------|----------------------|
| 1 | 9.44089 | 3 | 59.65180 |

5.7 30-FT Simple Span Steel Noncomposite Beam Bridge

In a 30-ft span, simple steel noncomposite beam bridge, W27x84 is used for exterior beam. The cross section of the bridge is shown in Figure 15 [3]. The input data and rating results are given as below.

Preparation of the Input Data

File: Control Information

DC 1 : FIVE W27X84, 30-FT SIMPLE SPAN, STEEL NONCOMPOSITE BEAM BRIDGE

DC 2 : 1,2,3,2

DC 3 : 3,4

DC 4 : 2,0,1,1,1,0,1,7000.0

For Beam/Girder Bridge

DC 1 : 1,1.4

DC 2 : 1,1.19,1.19

DC 3.1.1 : 30.0

DC 4.1 : 36.0

DC 4.1.1.1 : 211.7,211.7,26:69,0.463

For Fatigue Analysis, only for steel bridges

DC 1 : 3

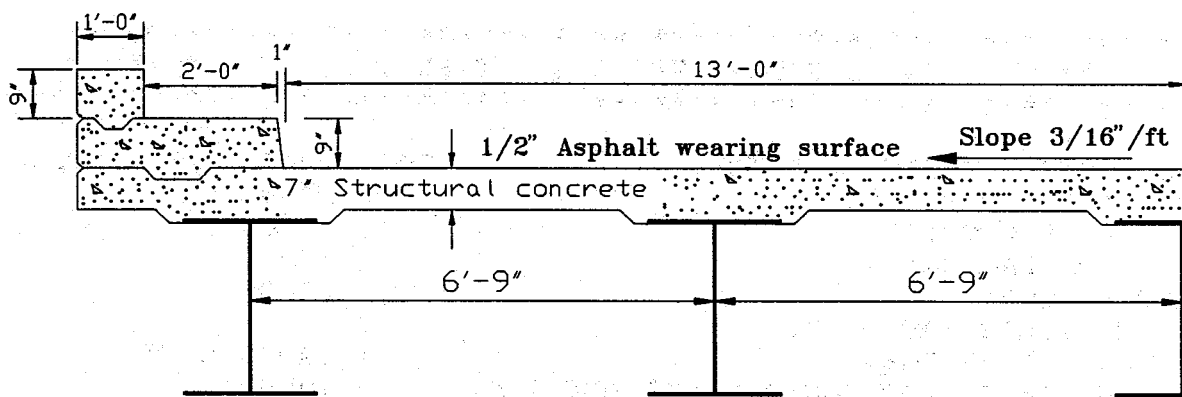


Figure 15. Cross Section of Simple Span Steel Beam Bridge.

The Input Data File Is Printed Out As:

FIVE W27X84, 30-FT SIMPLE SPAN, STEEL NONCOMPOSITE BEAM BRIDGE

1,2,3,2

3,4

2,0,1,1,1,0,1,7000.0

1,1.4

1,1.19,1.19

30.0

36.0 211.7,211.7,26.69,0.463

3

The Output Result File Is Given As:

FIVE W27X84, 30-FT SIMPLE SPAN, STEEL NONCOMPOSITE BEAM BRIDGE

NO. 1 RATING VEHICLE: TYPE 3-3

| | |
|---|----------------------|
| AVERAGE DAILY TRUCK TRAFFIC: | 7000.0000 TRUCKS/DAY |
| DEAD LOAD FACTOR: | 1.20000 |
| LIVE LOAD FACTOR: | 1.45000 |
| RESISTANCE FACTOR: | .65000 |
| IMPACT FACTOR: | .20000 |
| FATIGUE STRESS CATEGORY: | C |
| DEAD LOAD OF BRIDGE: | 1.40000 K/FT |
| DISTRIBUTION FACTOR FOR BENDING MOMENT: | 1.19000 |
| DISTRIBUTION FACTOR FOR SHEAR: | 1.19000 |
| BRIDGE LENGTH: | 30.00000 FT |
| YIELD STRENGTH OF STEEL: | 36.00000 KSI |

SECTION PROPERTIES AT THE' MIDDLE SPAN

| | |
|---------------------------------------|--------------------|
| PLASTIC SEC. MODULUS FOR TOP SEC.: | 211.70000 IN*IN*IN |
| PLASTIC SEC. MODULUS FOR BOTTOM SEC.: | 211.70000 IN*IN*IN |
| DEPTH OF SECTION: | 26.69000 IN |
| THICKNESS OF WEB: | .46300 IN |

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | TYPE 3-3 | 1.19 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | TYPE 3-3 | 4.55 |
| 2 | TYPE 3-3 | 4.55 |

THE FATIGUE LIFE FOR SIMPLE SPAN BRIDGE

POSITIVE MOMENT

| SPAN STRESS RANGE (KSI) | EQUIVALENT | NUMBER OF CYCLES FOR 1 TRUCK (S) | FATIGUE LIFE (YEARS) |
|-------------------------|------------|----------------------------------|----------------------|
| 1 | 4.91588 | 4 | INFINITE |

***** NO. 2 RATING VEHICLE: HS20-44 *****

AVERAGE DAILY TRUCK TRAFFIC: 7000.00000 TRUCKS/DAY

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR 1 |
|------|----------------|-----------------|
| | HS20-44 | .80 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | HS20-44 | 2.89 |
| 2 | HS20-44 | 2.89 |

THE FATIGUE LIFE FOR SIMPLE SPAN BRIDGE

POSITIVE MOMENT

| SPAN | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|------|-------------------------------------|------------------------------------|-------------------------|
| 1 | 8.67485 | 3 | 55.64521 |

Figures 16 and 17 are the shear and moment envelopes for the HS -20-44 truck load, respectively. The bending stress history at midspan is shown in Figure 18.

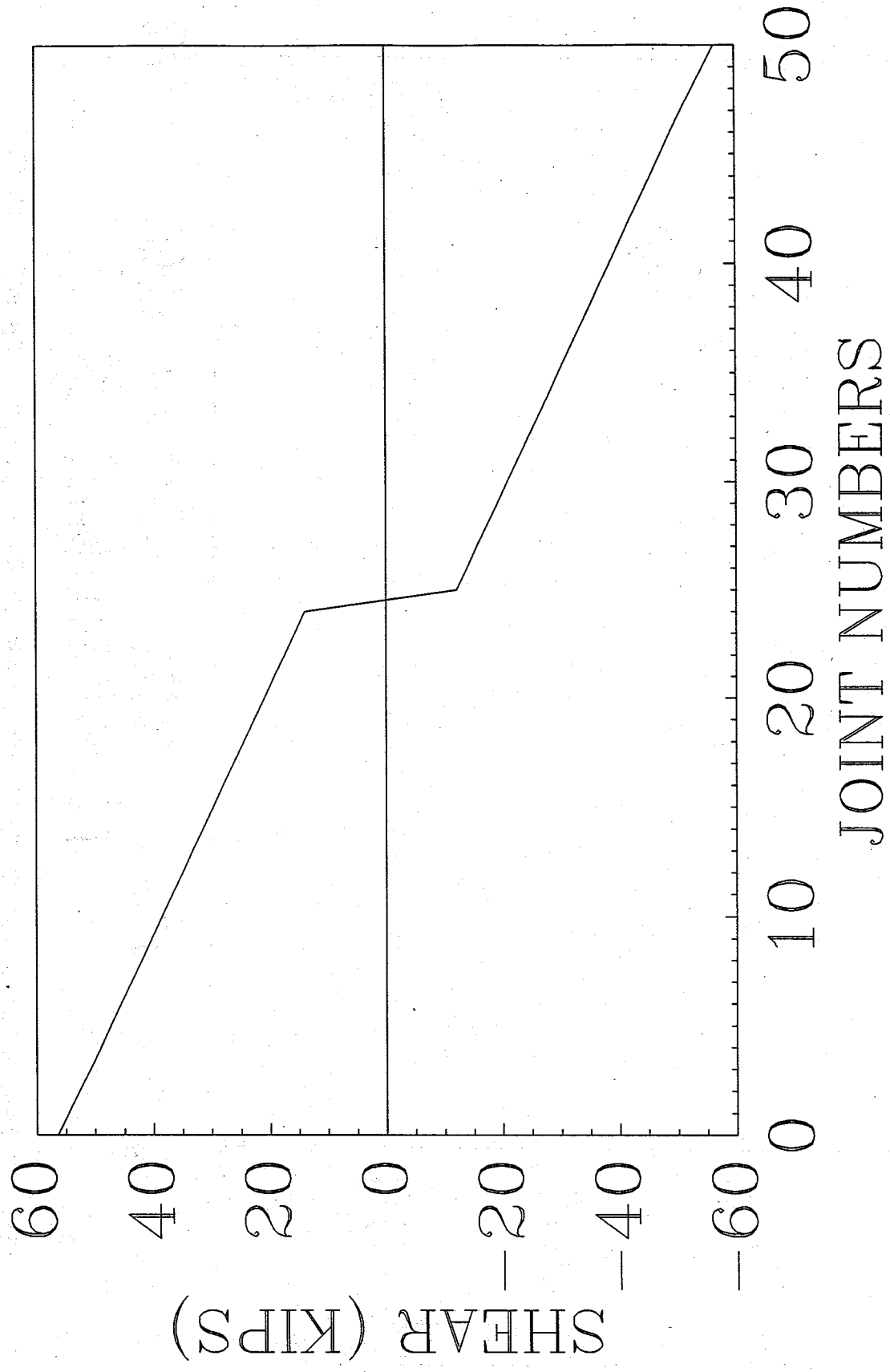


Figure 16. Shear Envelope of HS 20-44 Truck Loading for 30-ft Simple Span Bridge in Example #7.

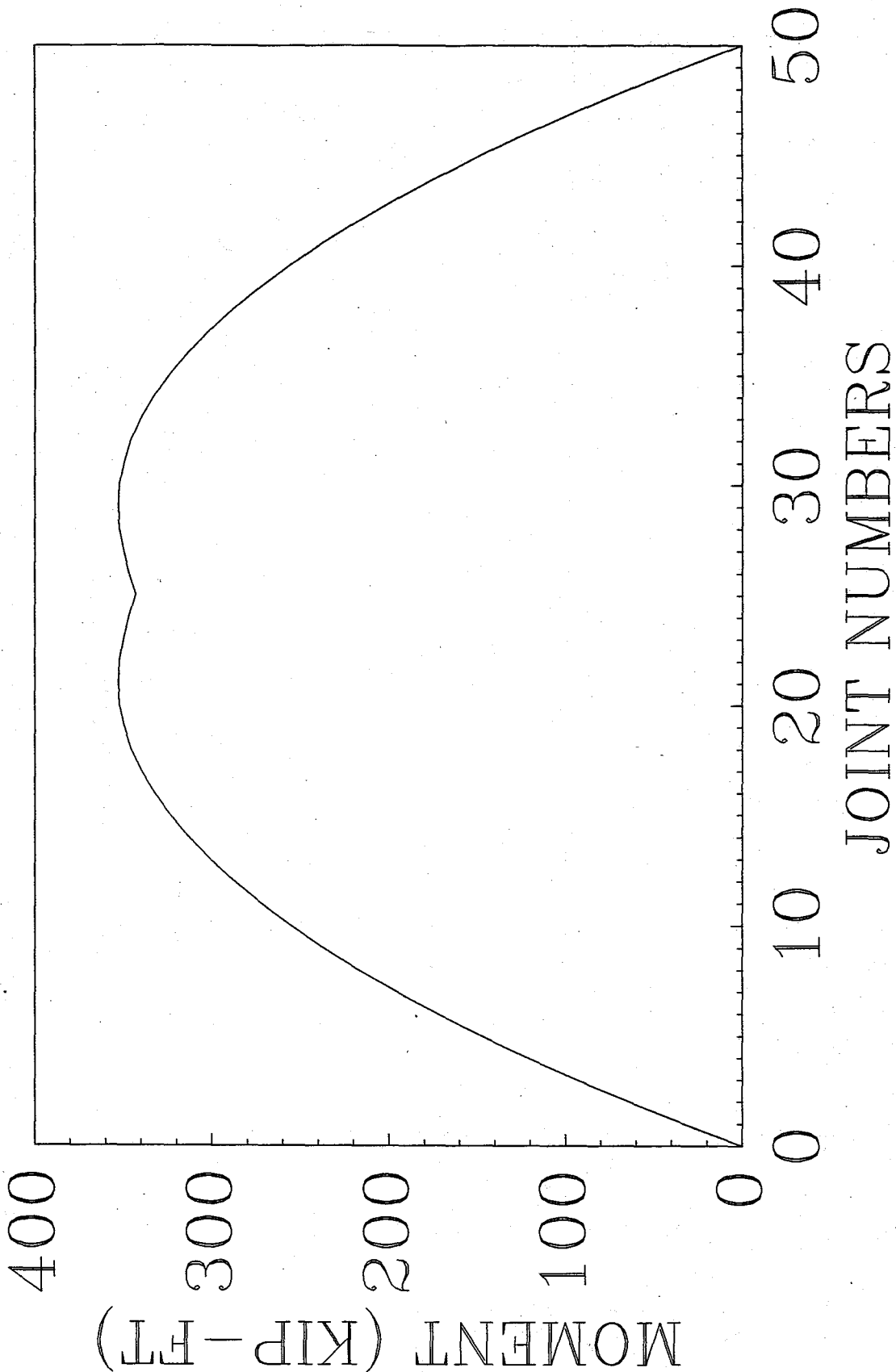


Figure 17. Moment Envelope of HS 20-44 Truck Loading for 30-ft Simple Span Bridge in Example #7.

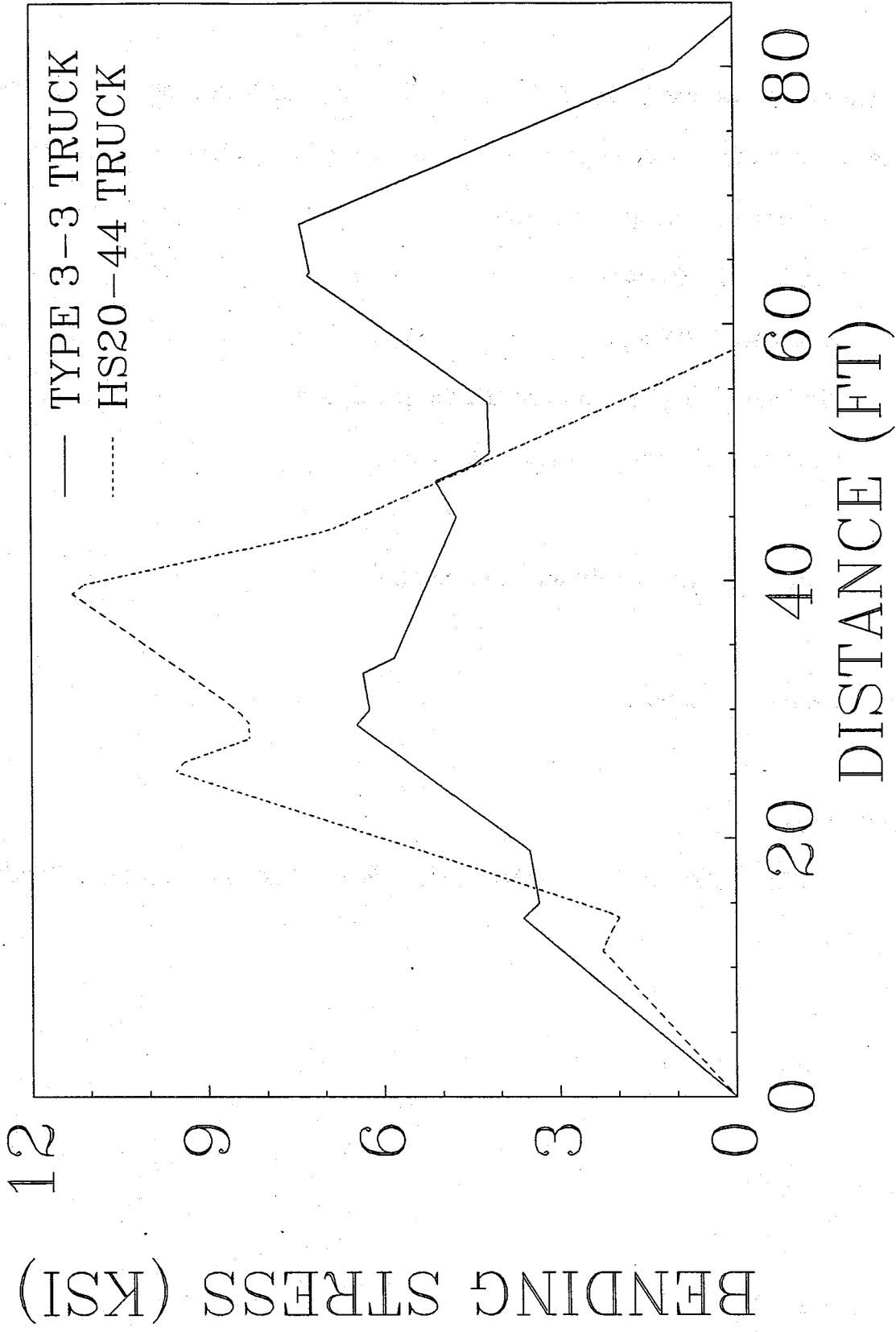


Figure 18. The Bending Stress History at Midspan in Example #7.

5.8 Three Continuous Span Nonuniform Section Steel Girders

A three-span continuous bridge with spans of 99, 132, and 99ft. is studied [4]. The girder spans, cross section, and flange plate design are shown in Figures 19, 20 and 21 respectively. The basic data are given as below:

Live load: HS 20-44 truck

Dead load: 2.284 kips/ft

Distribution factor for moment and shear: 2.5, and

Modulus of elasticity of girder: 29×10^6 psi.

The input data and rating results are given as below.

Preparation of the Input Data File:

Control Information

DC 1 : THREE CONTINUOUS SPAN, NONUNIFORM SECTION STEEL GIRDERS

DC 2 : 1,2,3,2

DC 3 : 3,4

DC 4 : 2,0;1,1,1,0,1,5000.0

For Beam/Girder Bridge

DC 1 : 2,2.284

DC 2 : 1,2.5,2.5

DC 3.2.1 : 3,29000.0

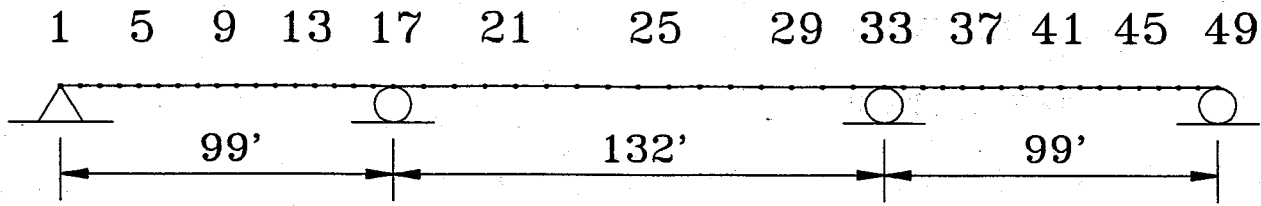


Figure 19. Girder Spans of Continuous Bridge
 Symm.

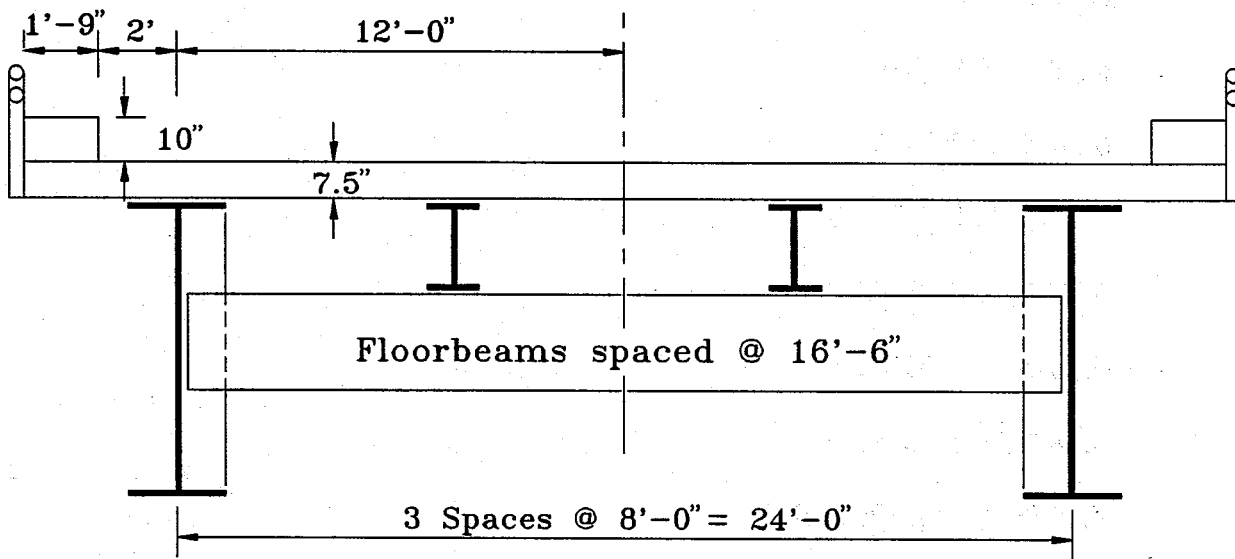


Figure 20. Cross Section of Continuous Steel Girder Bridge

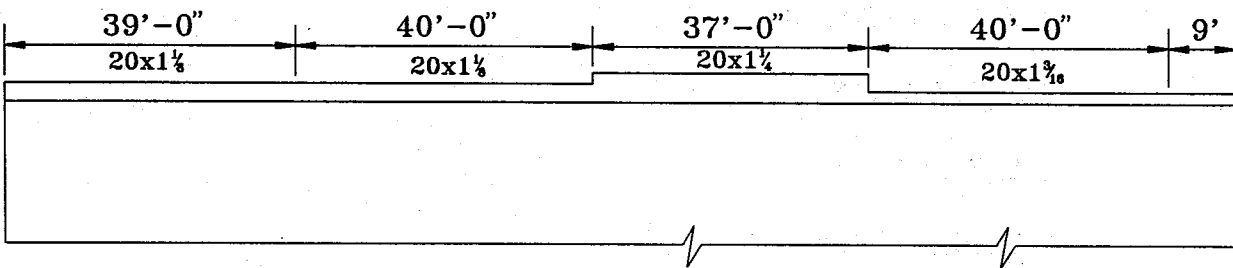


Figure 21. Flange Design for Continuous Steel Girder Bridge

DC 3.2.2 : 6.1875,76.5,73765:0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,121.5,137652.0

6.1875,121.5,137652.0

6.1875,121.5,137652.0

6.1875,121.5,137652.0

8.25,121.5,137652.0

8.25,121.5,137652.0

8.25,790,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,77215.0

8.25,79.0,772 15.0

8.25,121.5,137652.0

8.25,121.5,137652.0

6.1875,121.5,137652.0

6.1875,121.5,137652.0

6.1875,12 1.5,137652.0

6.1875,121.5,137652.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

DC 4.1 : 36.0
DC 4.1.2.1 : 2225.44,2325.12,2225.44
DC 4.1.2.2 : 2225.44,2325.12,2225.44
DC 4.1.2.3 : 4030.88,4030.88
DC 4.1.2.4 : 198.0,198.0
DC 4.1.2.5 : 20.0,20.0
DC 4.1.2.6 : 74.25,76.5,76.5,74.25
DC 4.1.2.7 : 0.4375,0.4375,0.4375,0.4375
DC 4.1.2.8 : 4.969,4.969

For Fatigue Analysis only for steel bridges

DC 1 : 6

The Input Data File Is Printed Out As:

THREE CONTINUOUS SPAN, NONUNIFORM SECTION STEEL GIRDERS

1,2,3,2

3,4 2,0,1,1,1,0,1,5000.0

2,2.284

1,2.5,2.5 3,29000.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,7645,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,76.5,73765.0

6.1875,121.5,137652.0

6.1875,121.5,137652.0

6.1875,121.5,137652.0

6.1875,121.5,137652.0
8.25,121.5,137652.0
8.25,121.5,137652.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,79.0,77215.0
8.25,121.5,137652.0
8.25,121.5,137652.0
6.1875,121.5,137652.0
6.1875,121.5,137652.0
6.1875,121.5,137652.0
6.1875,121.5,137652.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0
6.1875,76.5,73765.0

AVERAGE DAILY TRUCK TRAFFIC: 5000.00000-TRUCKS/DAY
 DEAD LOAD FACTOR: 1.20000
 LIVE LOAD FACTOR 1.45000
 RESISTANCE FACTOR: .65000
 IMPACT FACTOR: .20000
 FATIGUE STRESS CATEGORY: E
 DEAD LOAD OF BRIDGE: 2.28400 K/FT
 DISTRIBUTION FACTOR FOR BENDING MOMENT: 2.50000
 DISTRIBUTION FACTOR FOR SHEAR: 2.50000
 MODULUS OF ELASTICITY OF BRIDGE: 29000.00000 KSI
 YIELD STRENGTH OF STEEL: 36.00000 KSI PLASTIC

SECTION MODULUS AT THE MAX. POSITIVE MOMENT POINT

| TOP SECTION | BOTTOM SECTION | (IN*IN*IN) | (IN*IN*IN) |
|-------------|----------------|------------|------------|
| 1 | 2225.44000 | 2225.44000 | |
| 2 | 2325.12000 | 2325.12000 | |
| 3 | 2225.44000 | 2225.44000 | |

SECTION PROPERTIES AT EACH SUPPORT (NEGATIVE MOMENT)

| SUPPORT | DEPTH (IN) | WEB THICKNESS (IN) | RAD. OF GYR. (Y-Y) (IN) |
|---------|---------------|-----------------------|----------------------------|
| 1 | 74.25000 | .43750 | |
| 2 | 76.50000 | .43750 | 4.96900 |
| 3 | 76.50000 | .43750 | 4.96900 |
| 4 | 74.25000 | .43750 | |

| SUPPORT | PLASTIC SEC. MOD. (IN*IN*IN) | UNBRACED LENGTH (IN) | FLANGE WIDTH (IN) |
|---------|---------------------------------|-------------------------|----------------------|
| 2 | 4030.88000 | 198.00000 | 20.00000 |
| 3 | 4030.88000 | 198.00000 | 20.00000 |

| ELE. | LENGTH (FT) | CROSS AREA (IN*IN) | MOMENT OF INERTIA (IN*IN*IN*IN) |
|------|----------------|-----------------------|------------------------------------|
| 1 | 6.18750 | 76.50000 | 73765.00000 |
| 2 | 6.18750 | 76.50000 | 73765.00000 |
| 3 | 6.18750 | 76.50000 | 73765.00000 |
| 4 | 6.18750 | 76.50000 | 73765.00000 |
| 5 | 6.18750 | 76.50000 | 73765.00000 |
| 6 | 6.18750 | 76.50000 | 73765.00000 |
| 7 | 6.18750 | 76.50000 | 73765.00000 |
| 8 | 6.18750 | 76.50000 | 73765.00000 |
| 9 | 6.18750 | 76.50000 | 73765.00000 |
| 10 | 6.18750 | 76.50000 | 73765.00000 |
| 11 | 6.18750 | 76.50000 | 73765.00000 |
| 12 | 6.18750 | 76.50000 | 73765.00000 |
| 13 | 6.18750 | 121.50000 | 137652.00000 |
| 14 | 6.18750 | 121.50000 | 137652.00000 |
| 15 | 6.18750 | 121.50000 | 137652.00000 |
| 16 | 6.18750 | 121.50000 | 137652.00000 |
| 17 | 8.25000 | 121.50000 | 137652.00000 |
| 18 | 8.25000 | 121.50000 | 137652.00000 |
| 19 | 8.25000 | 79.00000 | 77215.00000 |
| 20 | 8.25000 | 79.00000 | 77215.00000 |

| | | | |
|----|---------|-----------|--------------|
| 21 | 8.25000 | 79.00000 | 77215.00000 |
| 22 | 8.25000 | 79.00000 | 77215.00000 |
| 23 | 8.25000 | 79.00000 | 77215.00000 |
| 24 | 8.25000 | 79.00000 | 77215.00000 |
| 25 | 8.25000 | 79.00000 | 77215.00000 |
| 26 | 8.25000 | 79.00000 | 77215.00000 |
| 27 | 8.25000 | 79.00000 | 77215.00000 |
| 28 | 8.25000 | 79.00000 | 77215.00000 |
| 29 | 8.25000 | 79.00000 | 77215.00000 |
| 30 | 8.25000 | 79.00000 | 77215.00000 |
| 31 | 8.25000 | 121.50000 | 137652.00000 |
| 32 | 8.25000 | 121.50000 | 137652.00000 |
| 33 | 6.18750 | 121.50000 | 137652.00000 |
| 34 | 6.18750 | 121.50000 | 137652.00000 |
| 35 | 6.18750 | 121.50000 | 137652.00000 |
| 36 | 6.18750 | 121.50000 | 137652.00000 |
| 37 | 6.18750 | 76.50000 | 73765.00000 |
| 38 | 6.18750 | 76.50000 | 73765.00000 |
| 39 | 6.18750 | 76.50000 | 73765.00000 |
| 40 | 6.18750 | 76.50000 | 73765.00000 |
| 41 | 6.18750 | 76.50000 | 73765.00000 |
| 42 | 6.18750 | 76.50000 | 73765.00000 |
| 43 | 6.18750 | 76.50000 | 73765.00000 |
| 44 | 6.18750 | 76.50000 | 73765.00000 |
| 45 | 6.18750 | 76.50000 | 73765.00000 |
| 46 | 6.18750 | 76.50000 | 73765.00000 |
| 47 | 6.18750 | 76.50000 | 73765.00000 |
| 48 | 6.18750 | 76.50000 | 73765.00000 |

THE RATING RESULT FOR CONTINUOUS SPAN BEAM GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | TYPE 3-3 | 1.31 |
| | TYPE 3-3 | 1.20 |
| 3 | TYPE 3-3 | 1.31 |

NEGATIVE MOMENT

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 2 | TYPE 3-3 | 5.14 |
| 3 | TYPE 3-3 | 5.14 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | TYPE 3-3 | 2.99 |

| | | |
|---|----------|------|
| 2 | TYPE 3-3 | 1.92 |
| 3 | TYPE 3-3 | 1.92 |
| 4 | TYPE 3-3 | 2.99 |

THE FATIGUE LIFE FOR CONTINUOUS SPAN BRIDGE

POSITIVE MOMENT

| SPAN | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCKS | FATIGUE LIFE (YEARS) |
|------|-------------------------------------|----------------------------------|-------------------------|
| 1 | .79384 | 3 | 31.52459 |
| 2 | 5.74172 | 3 | 31.81076 |
| 3 | 5.67824 | 3 | 32.16639 |

NEGATIVE MOMENT

| SUPPORT | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|---------|-------------------------------------|------------------------------------|-------------------------|
| 1 | 3.34711 | 3 | 54.56894 |
| 2 | 3.33831 | 3 | 54.71281 |

NO. 2 RATING VEHICLE: HS 20-44

AVERAGE DAILY TRUCK TRAFFIC: 5000.00000 TRUCKS/DAY

THE RATING RESULT FOR CONTINUOUS SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | HS20-44 | 1.12 |
| 2 | HS20-44 | 1.05 |

| | | |
|-----------------|---------|------|
| 3 | HS20-44 | 1.12 |
| NEGATIVE MOMENT | | |

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 2 | HS20-44 | 3.55 |
| 3 | HS20-44 | 3.55 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | HS20-44 | 2.65 |
| 2 | HS20-44 | 1.73 |
| 3 | HS20-44 | 1.73 |
| 4 | HS20-44 | 2.65 |

THE FATIGUE LIFE FOR CONTINUOUS SPAN BRIDGE

POSITIVE MOMENT

| SPAN | EQUIVALENT STRESS RANGE | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE |
|-------|-------------------------|---------------------------------|--------------|
| (KSI) | | | (YEARS) |
| 1 | 6.66677 | 3 | 27.39682 |
| 2 | 6.54833 | 3 | 27.89235 |
| 3 | 6.72432 | 3 | 27.16235 |

NEGATIVE MOMENT

| SUPPORT | EQUIVALENT STRESS RANGE | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE |
|---------|-------------------------|---------------------------------|--------------|
| | (KSI) | | (YEARS) |
| 1 | 3.35055 | 3 | 54.51302 |
| 2 | 3.34542 | 3 | 54.59652 |

Figures 22 and 23 are the shear influence lines for all supports (joints 1, 17, 33, and 49). Figure 24 shows the moment influence lines for joints 9, 17, 25, 33, and 41. The shear and moment envelopes are shown in Figures 25 to Figure 28 for different loads. Figures 29 to Figure 33 show the bending stress histories at joints 9, 17, 25, 33, and 41.

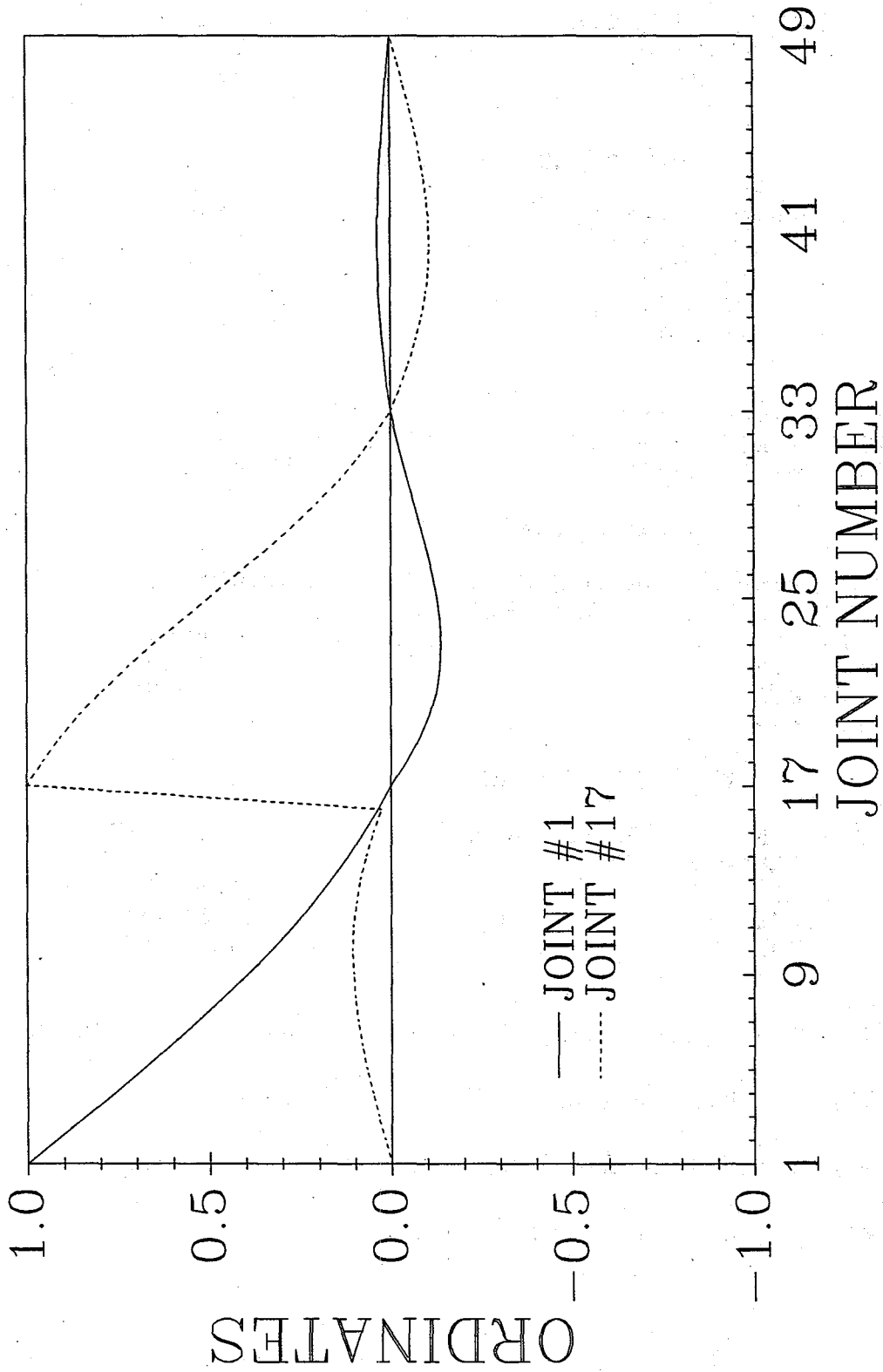


Figure 22. Shear Influence Lines of Joints #1 and #17 in Example #8.

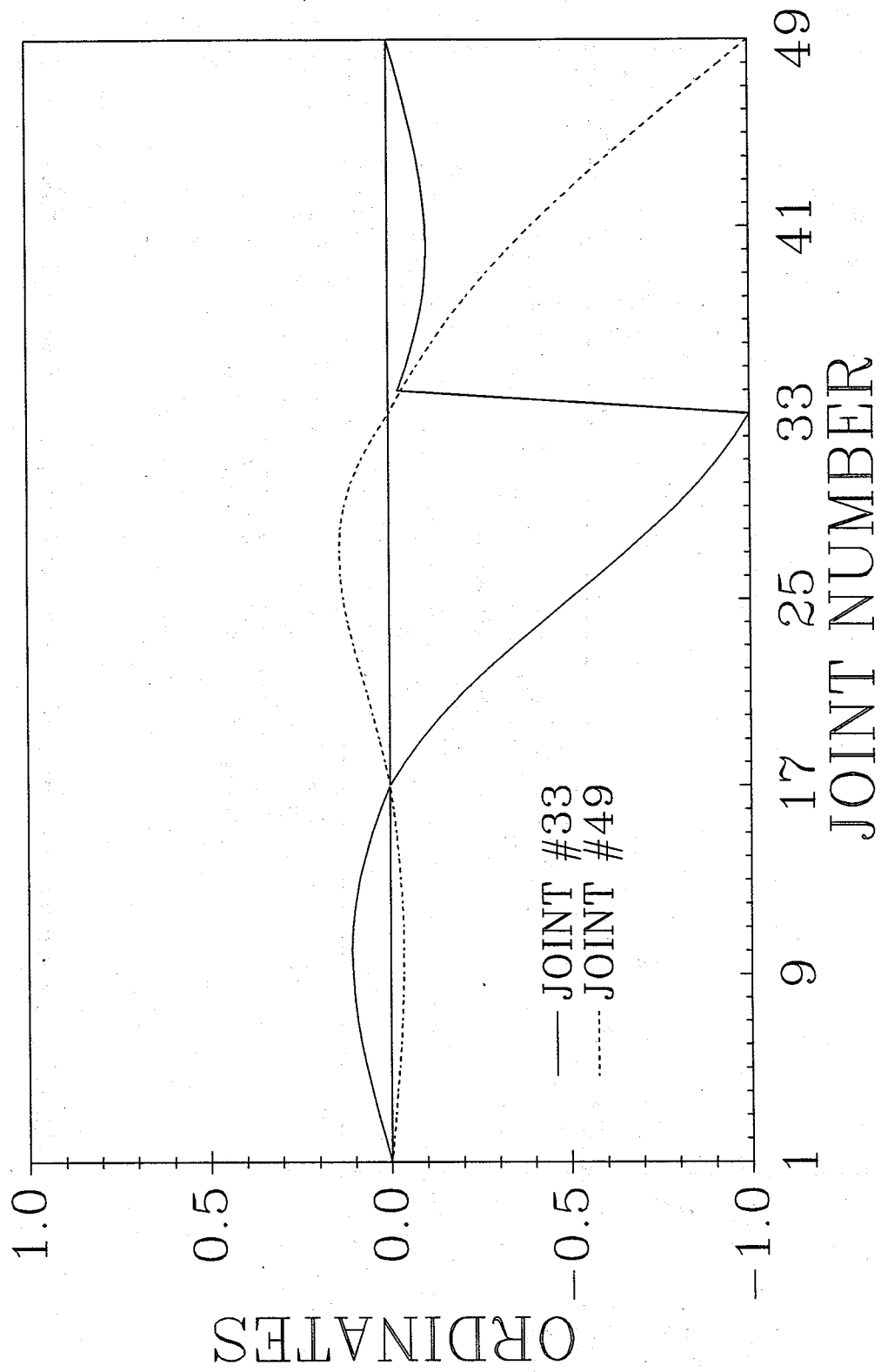


Figure 23. Shear Influence Lines of Joints #33 and #49 in Example #8.

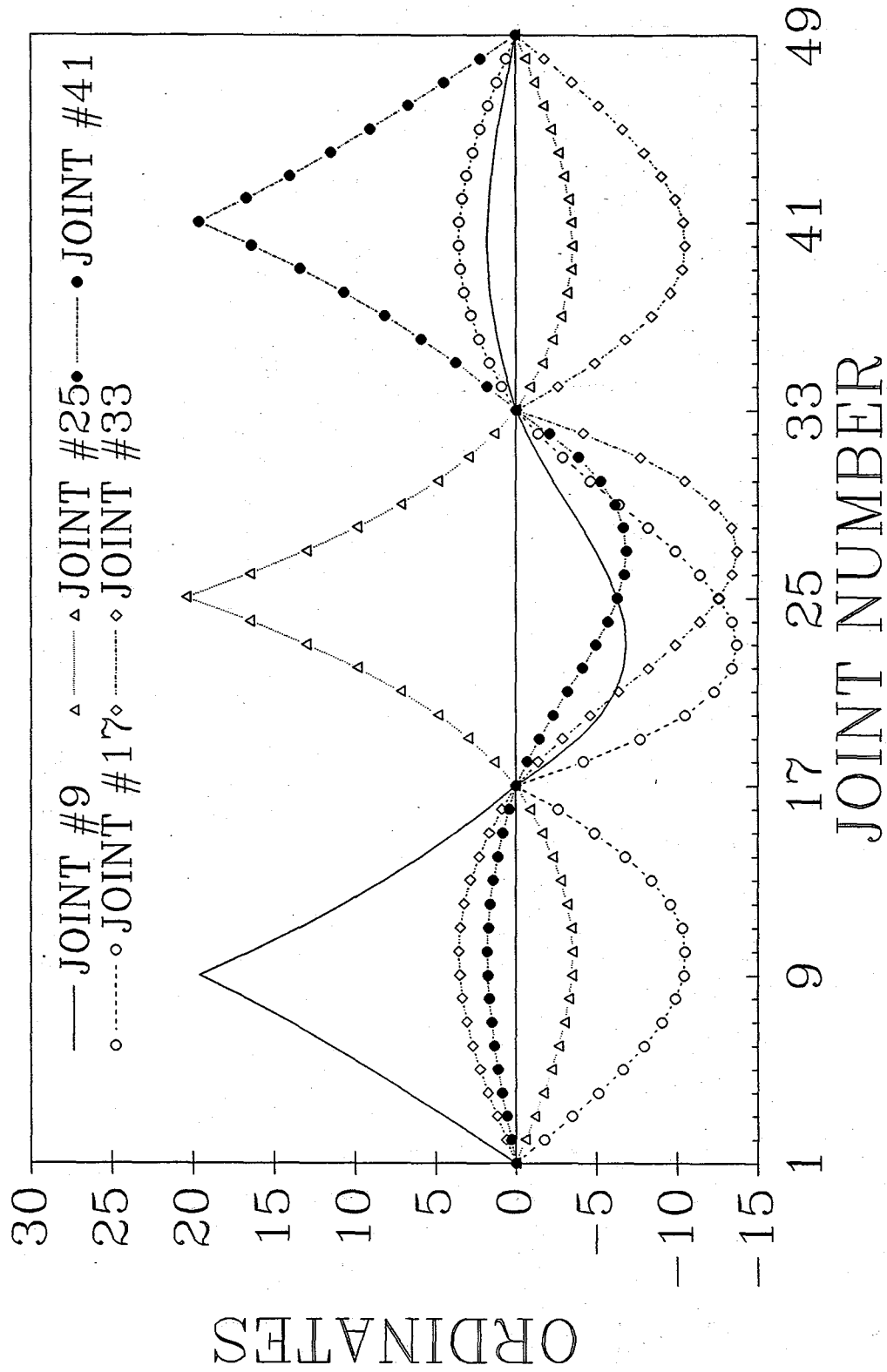


Figure 24. Moment Influence Lines of Joints #9, #17, #25, #33 and #41 in Example #8.

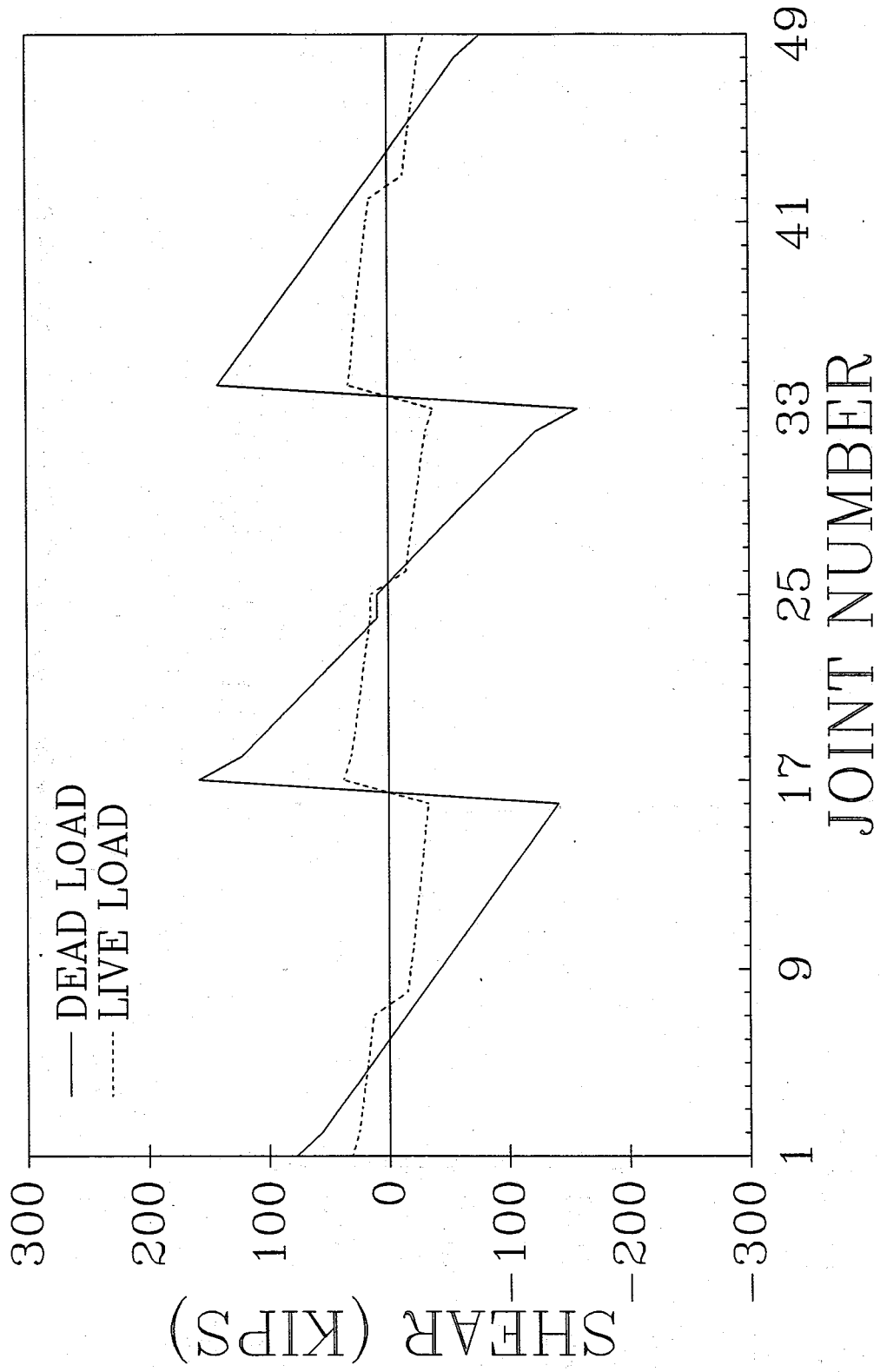


Figure 25. Shear Envelopes for Dead and Live Loads of HS 20-44 Truck in Example #8.

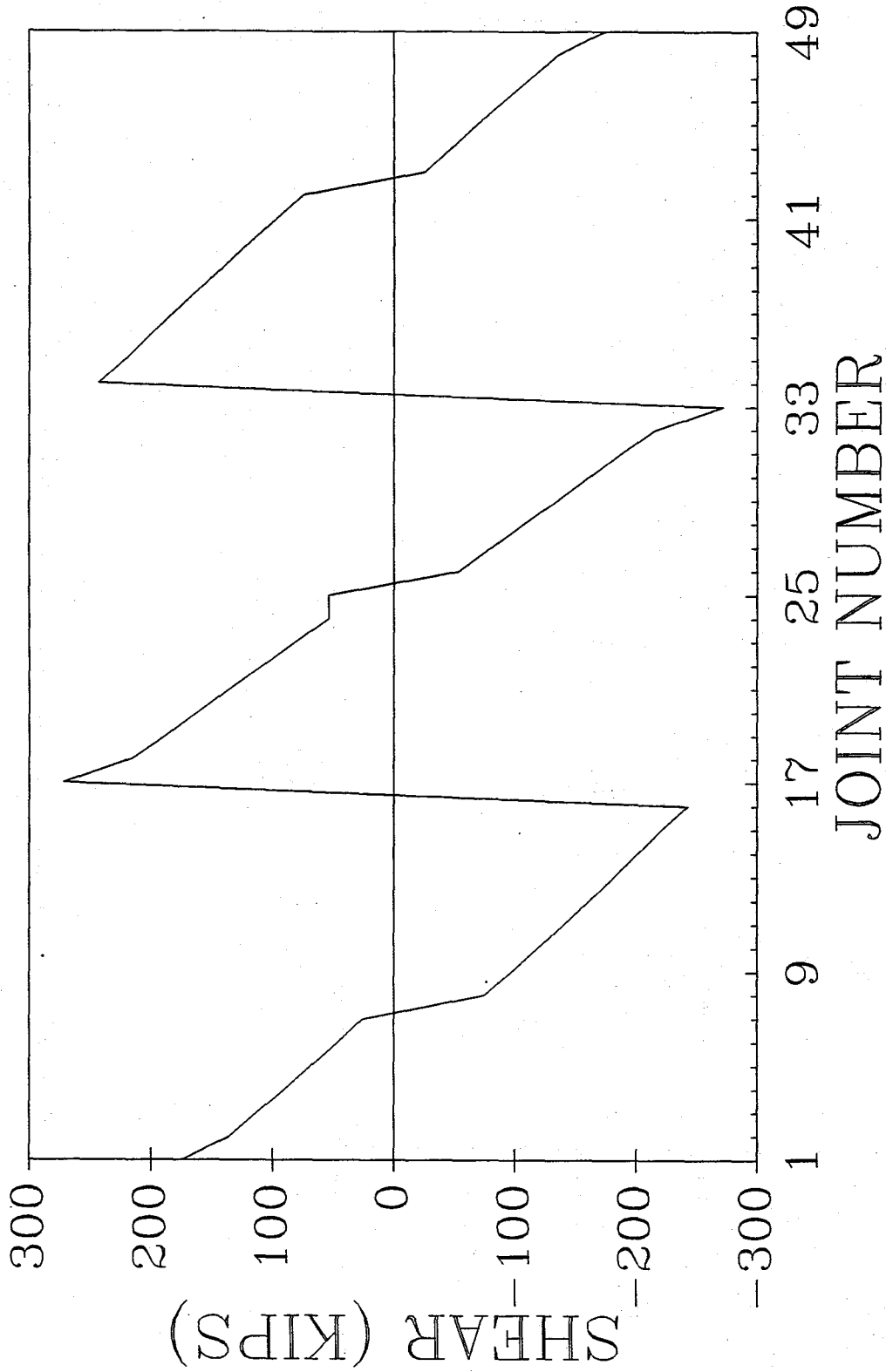


Figure 26. Shear Envelope for Total Load of HS 20-44 Truck in Example #8.

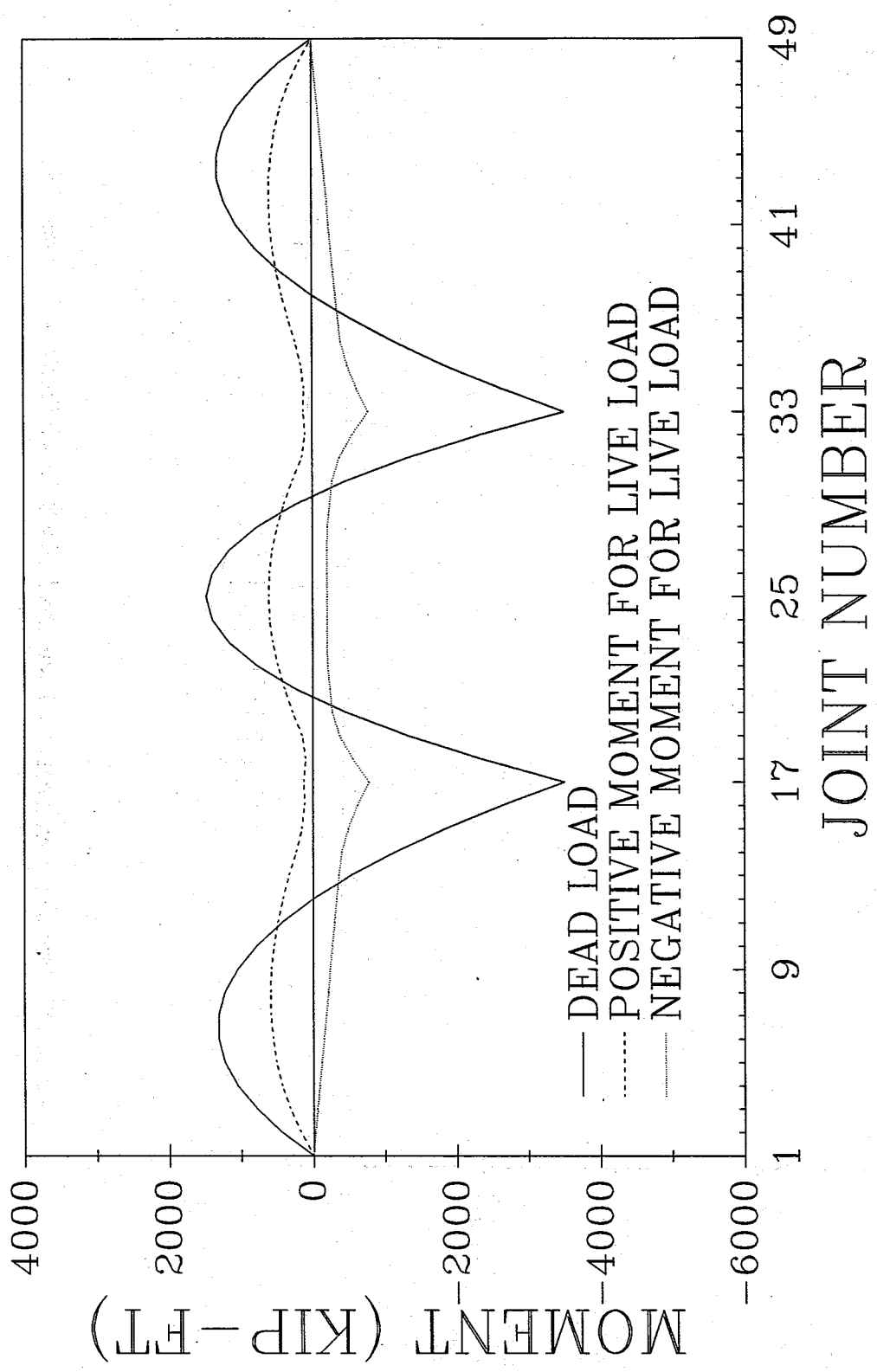


Figure 27. Moment Envelopes for Dead and Live Loads of HS 20-44 Truck in Example #8.

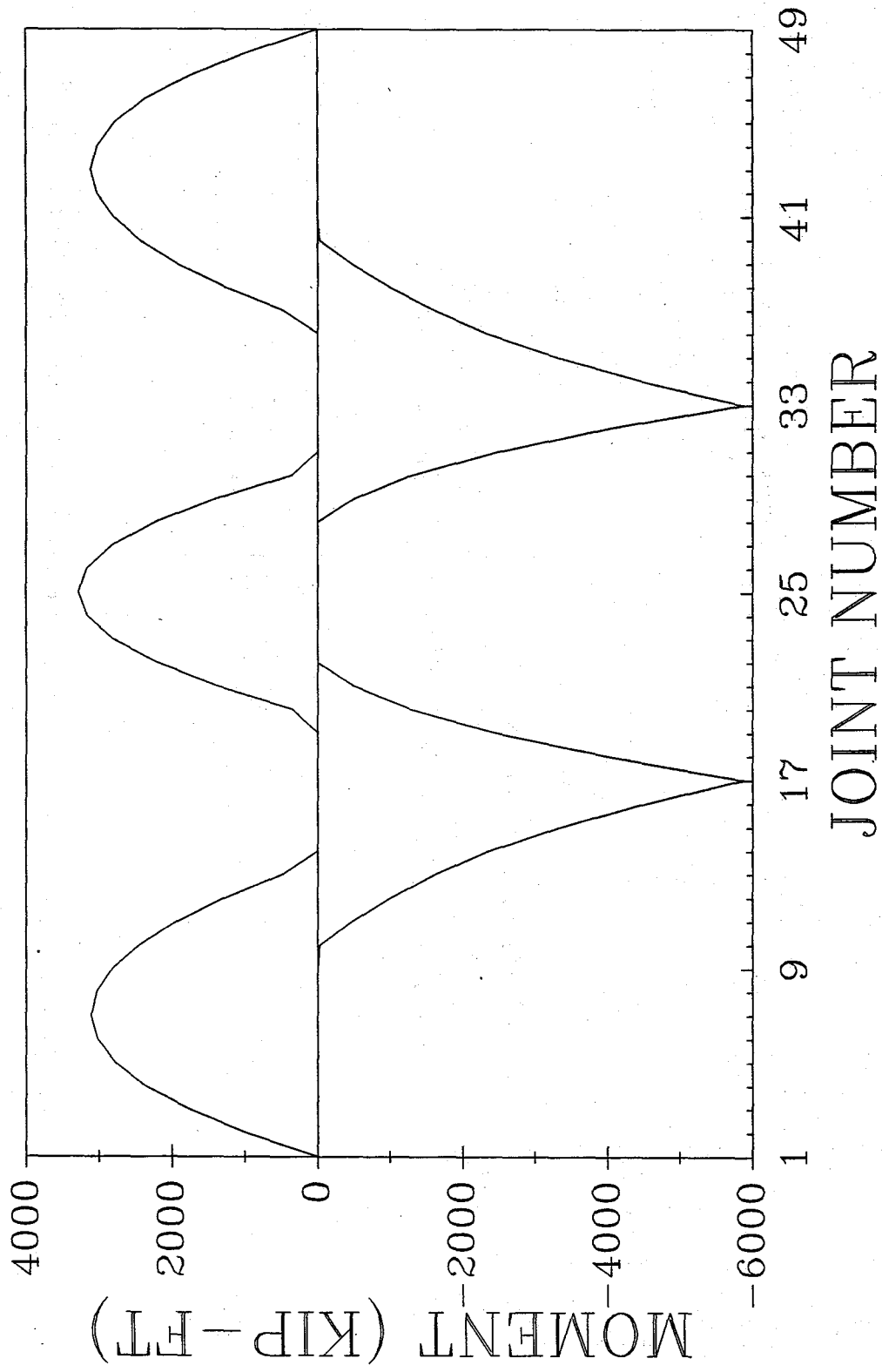


Figure 28. Moment Envelopes for Total Load of HS 20-44 Truck in Example #8.

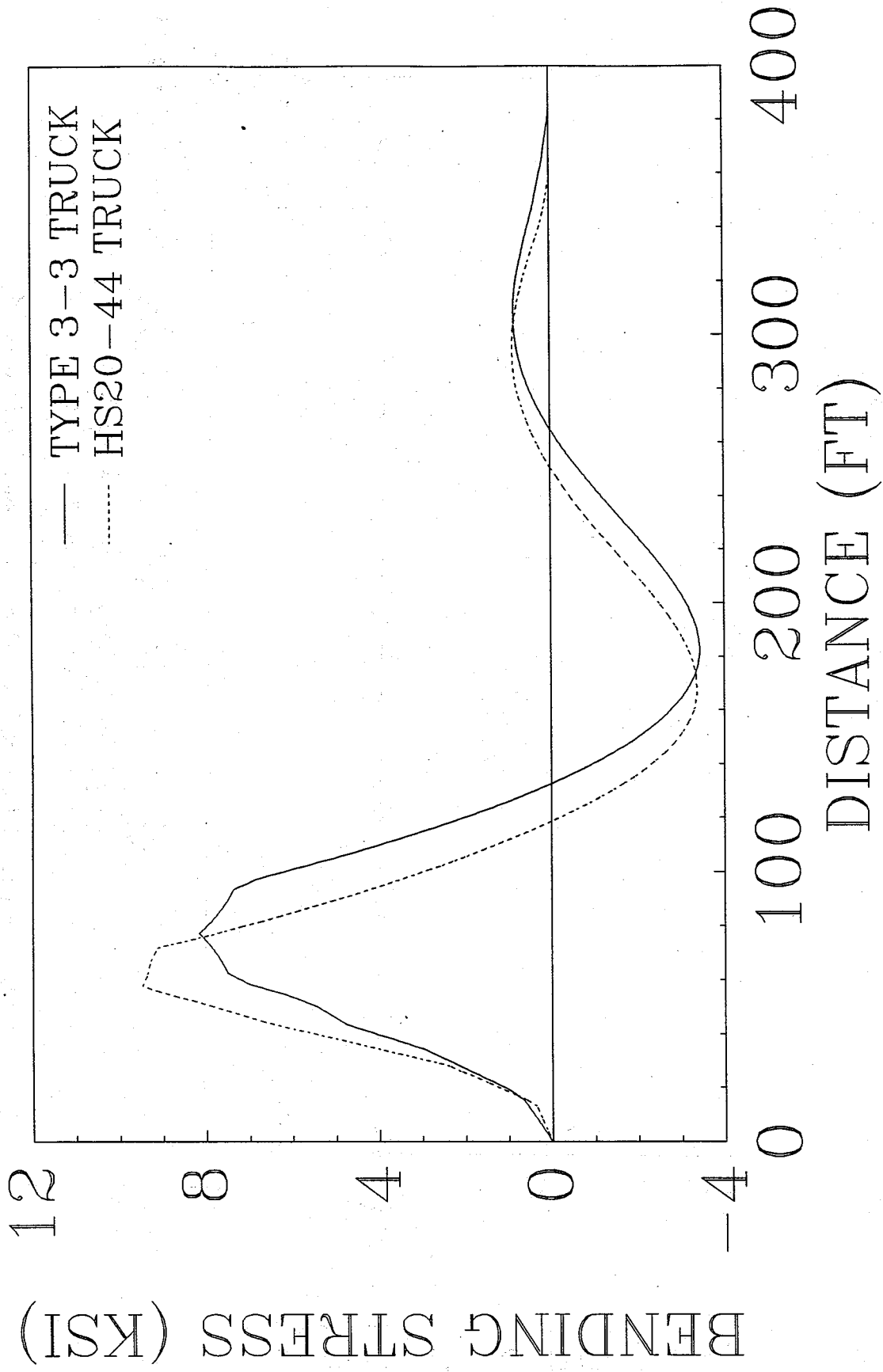


Figure 29. Maximum Positive Bending Stress History of Span #1 in Example #8.

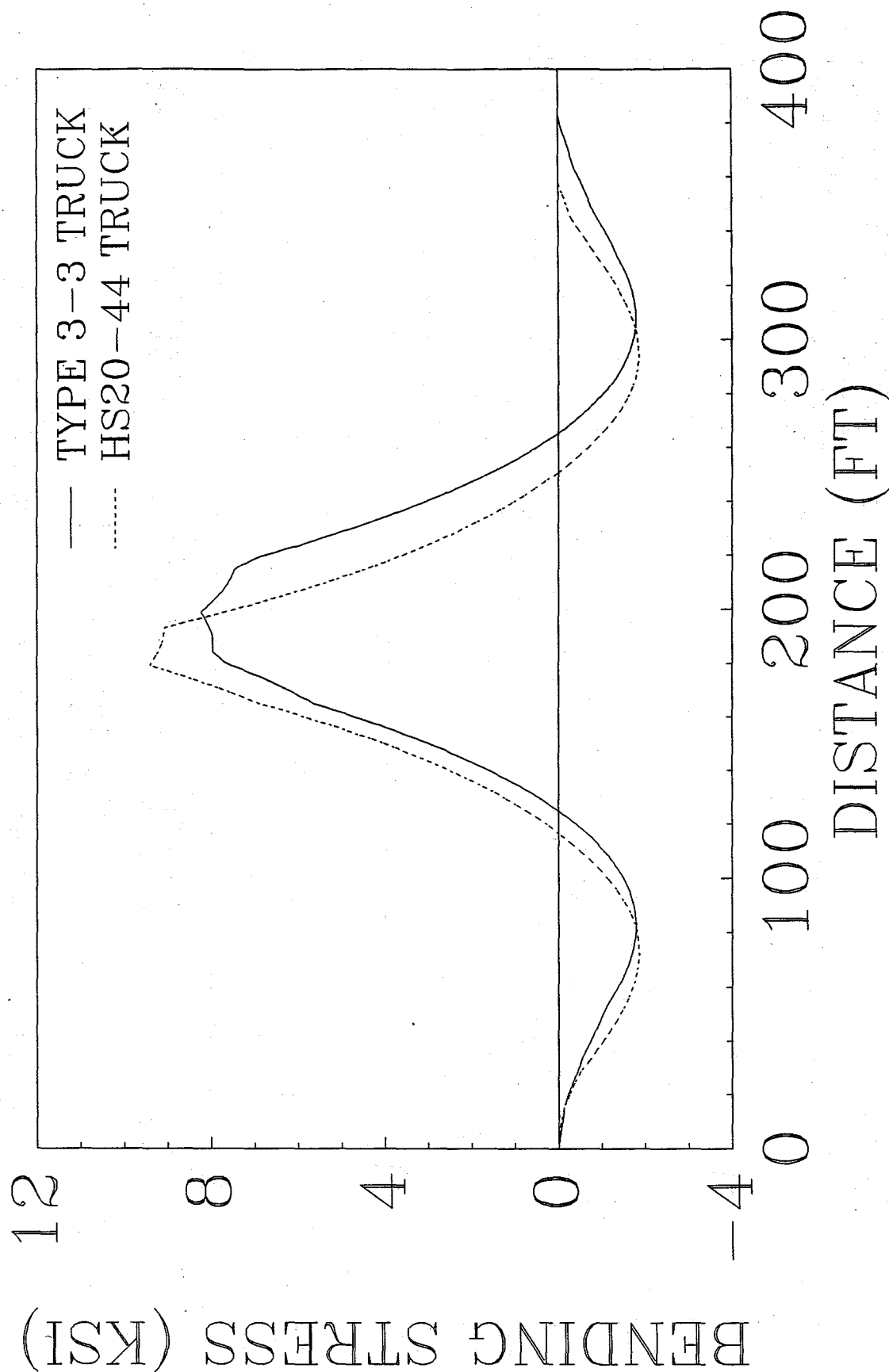


Figure 30. Maximum Positive Bending Stress History of Span #2 in Example #8.

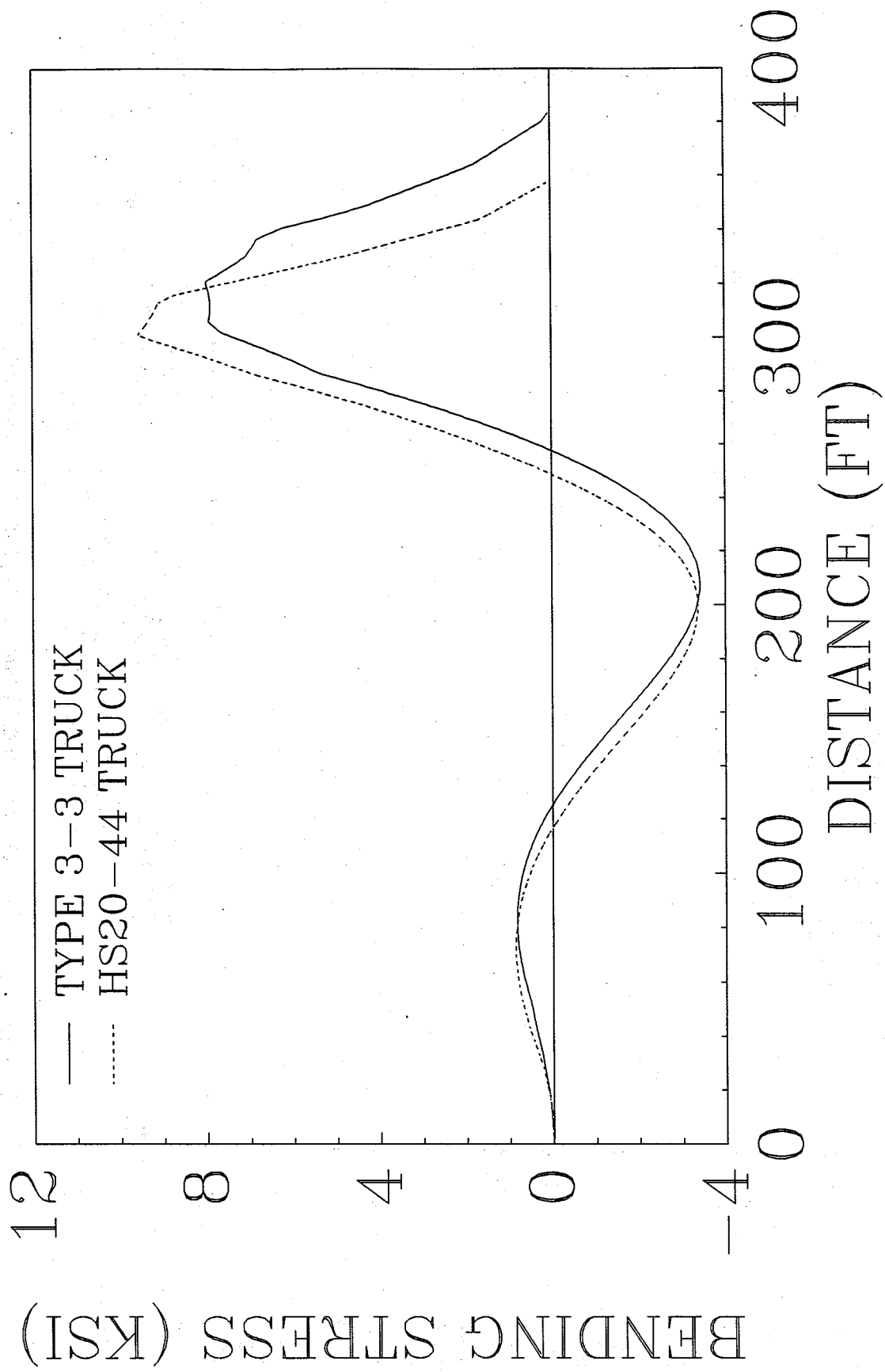


Figure 31. Maximum Positive Bending Stress History of Span #3 in Example #8.

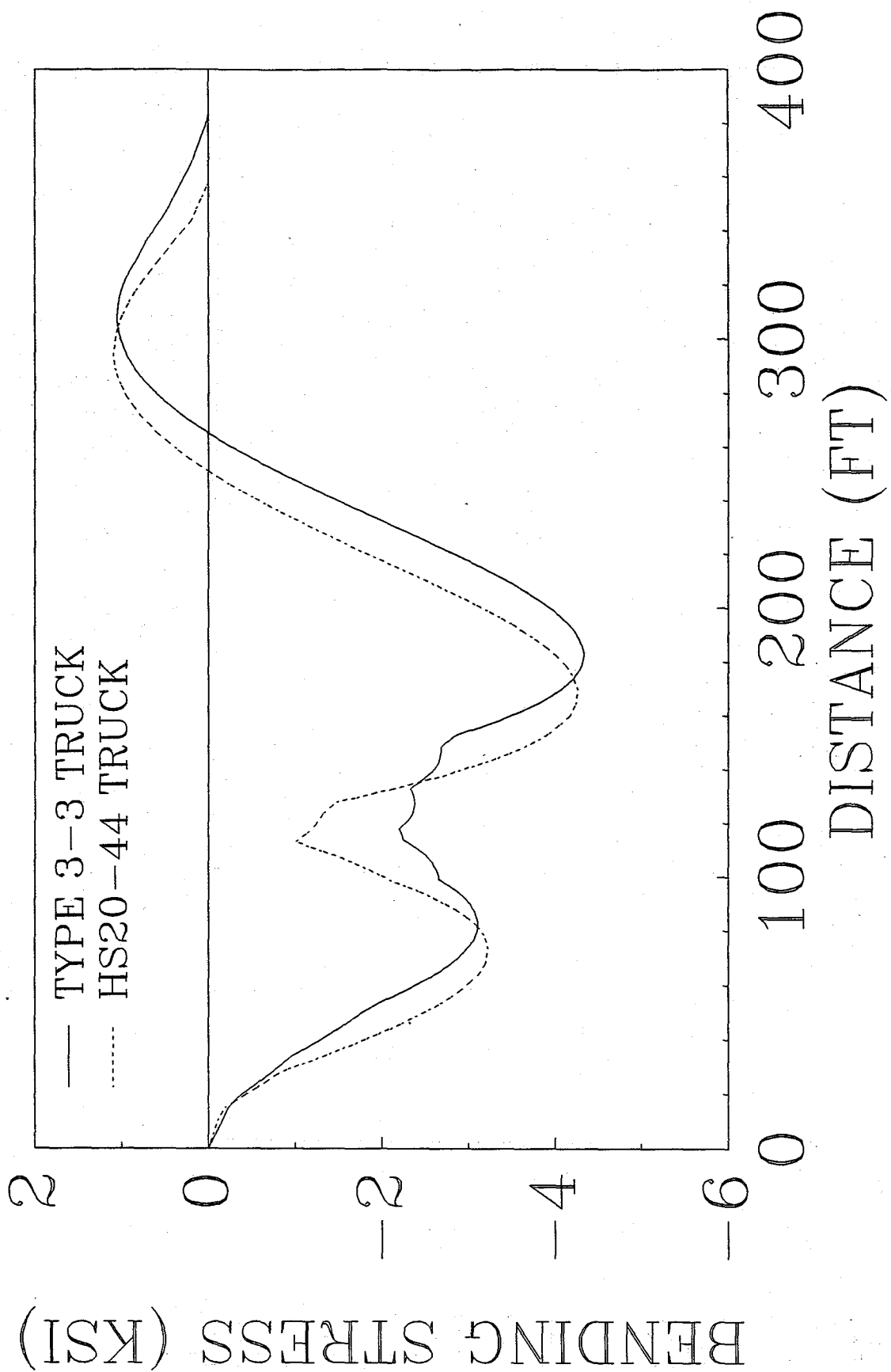


Figure 32. Negative Bending Stress History of Support #2 in Example #8.

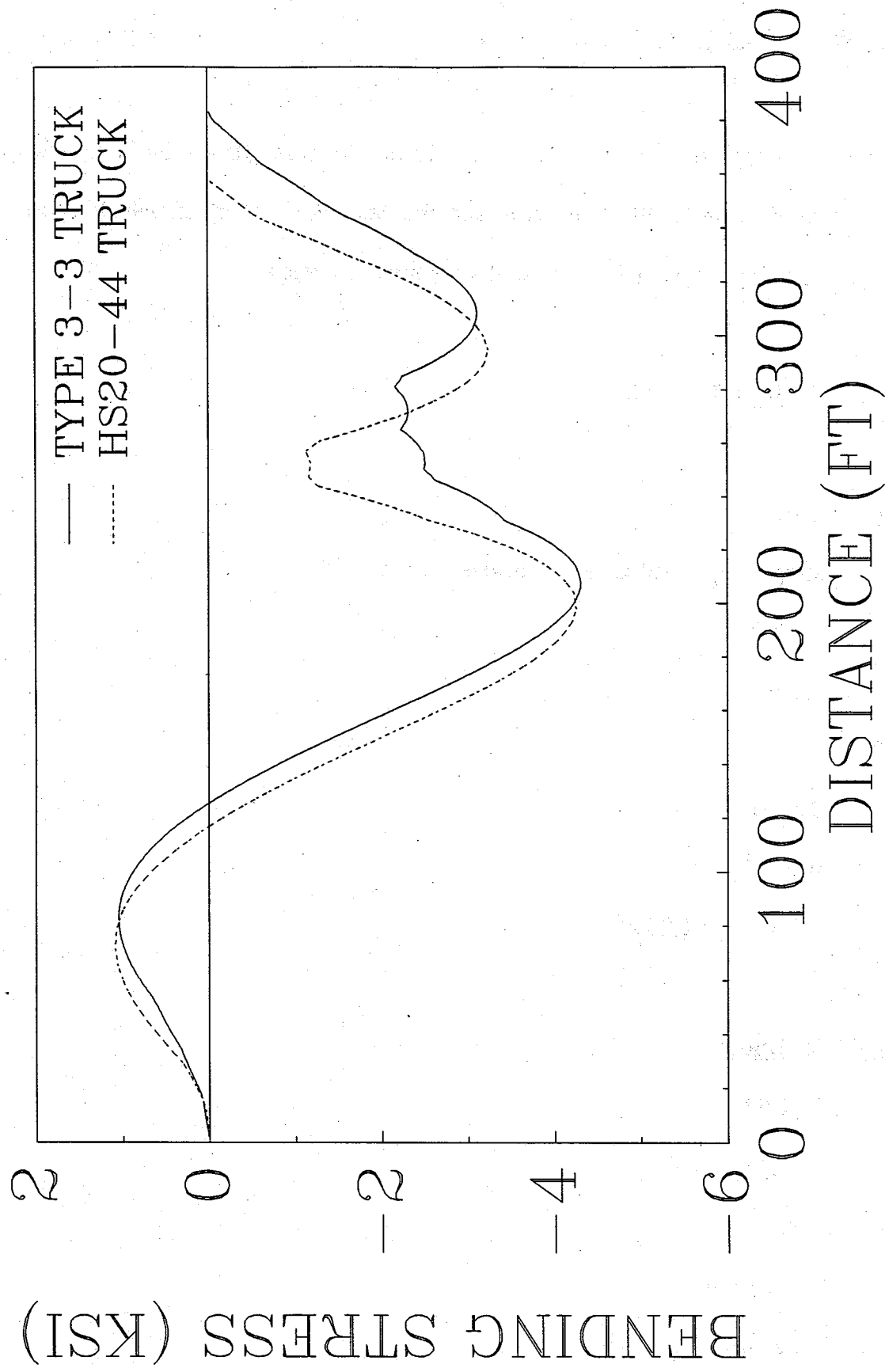


Figure 33. Negative Bending Stress History of Support #3 in Example #8.

5.9 65-FT Simple Span Concrete T-Beam Bridge

The T-beam superstructure for the bridge shown in Figures 10 and 34 is designed, by service load design for an HS20-44 live load and checked for the overload vehicle shown in Figure 33 [4]. The input data and rating results are given as below.

Preparation of the Input Data File:

Control Information

DC 1 : Simple Supported Concrete Bridge, T beam, 65 Feet
DC 2 : 1,1,3,2
DC 3 : 4,8
DC 3.1 : 4
DC 3.2 : 20.,20.,46.,46.
DC 3.3 : 4:5,8.25,4.5
DC 4 : 2,1,1,1,1,0,1,2000.

For Beam/Girder Bridge

DC 1 : 1,1.57
DC 2 : 2,1.167,1.167
DC 3.1.1 : 65.
DC 4.2 : 2,3.25,60.
DC 4.2.1.2 : 60.,15.,7.5,50,14.5

The Input Data File Is Printed Out As:

Simple Supported Concrete Bridge, T beam, 65 Feet

1,1,3,2

4,8

20.,20.,46.,46. 4.5,8.25,4.5

2,1,1,1,1,0,1,2000.

1,1.57

2,1.167,1.167 65.

2,3.25,60. 60.,15.,7.5,50.,14.5

The Output Result File Is Given As:

Simple Supported Concrete Bridge, T beam, 65 Feet

***** NO. 1 RATING VEHICLE: HS20-44 *****

AVERAGE DAILY TRUCK TRAFFIC: 2000.00000 TRUCKS/DAY

DEAD LOAD FACTOR: 1.20000

LIVE LOAD FACTOR: 1.45000

RESISTANCE FACTOR: .75000

IMPACT FACTOR: .20000

DEAD LOAD OF BRIDGE: 1.57000 K/FT

DISTRIBUTION FACTOR FOR BENDING MOMENT: 1.16700

DISTRIBUTION FACTOR FOR SHEAR: 1.16700

BRIDGE LENGTH: 65.00000 FT

ULTIMATE STRENGTH OF CONCRETE: 3.25000 KSI

YIELD STRENGTH OF REINFORCEMENT: 60.00000 KSI

FLANGE WIDTH OF T-SECTION: 60.00000 IN

WEB WIDTH OF T-SECTION: 15.00000 IN

FLANGE THICKNESS OF T-SECTION: 7.50000 IN

DEPTH OF T-SECTION: 50.00000 IN

AREA OF REINFORCEMENT: 14.50000 IN*IN

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | HS20-44 | 1.75 |

***** NO. 2 RATING VEHICLE: SPECIAL LOAD *****

AVERAGE DAILY TRUCK TRAFFIC: 2000.00000 TRUCKS/DAY *

THE RATING RESULT FOR SIMPLE SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | SPECIAL LOAD | .43 |

5.10 Three Continuous Span Composite Girder Bridge

This sample problem is for the rating of a three span continuous composite, hybrid steel structure. It is the bridge over the North, Platte River near Casper, Wyoming. The structure has three spans, 95'-6", 124'-0", and 95'-6".[6] It is composite steel and concrete in the positive moment regions and hybrid in the negative moment regions. A wearing surface of 3 inches of asphalt has been placed on the structure which is a sustained dead load in the composite sections. The modular ratio for a sustained dead load is 30 for the concrete used in this structure.

The framing plan and cross sections of the bridge are shown in Figures 35 and 36. The calculated dead load of the bridge is equal to 1.267 K/ft. The live load trucks for live load are HS 20-44, Type 3S2, and Type 3-3, respectively.

The input data and rating results are given as below.

Preparation of the Input Data File:

Control Information

DC 1 : Composite Steel Girder Bridge, Three Continuous Spans
DC 2 : 1,2,3,3
DC 3 : 472,1
DC 4 : 2,1,1,1,1,0,1,5000.

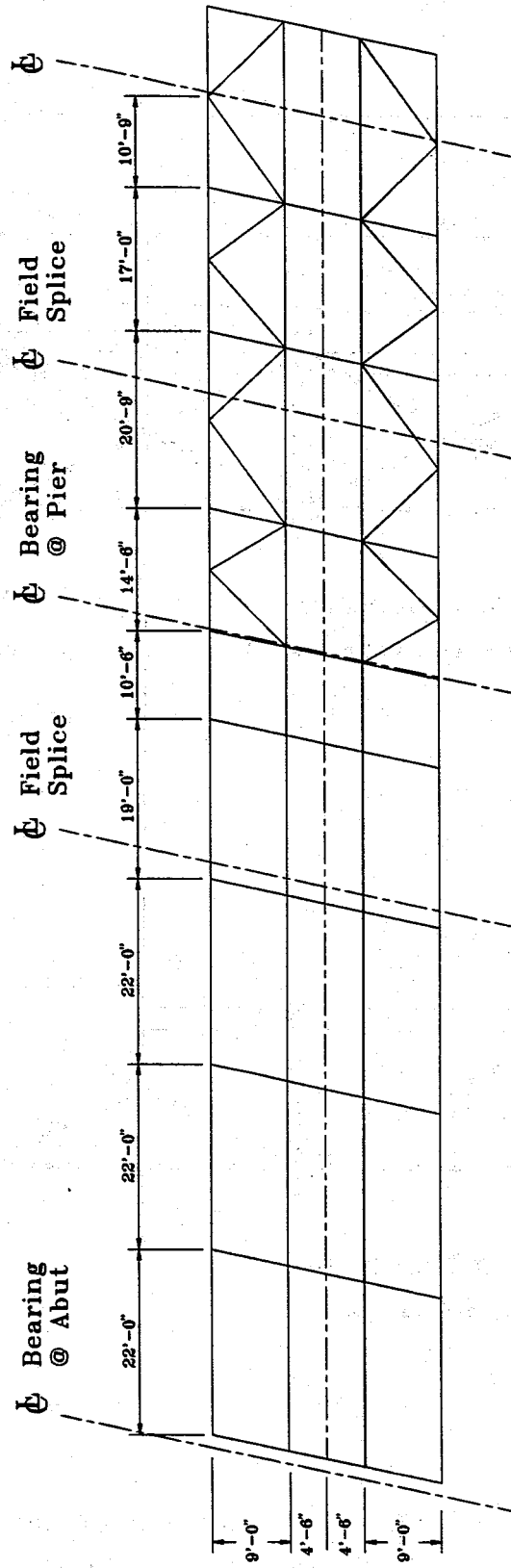


Figure 36. Framing Plan of the Three-Span Continuous Composite Bridge

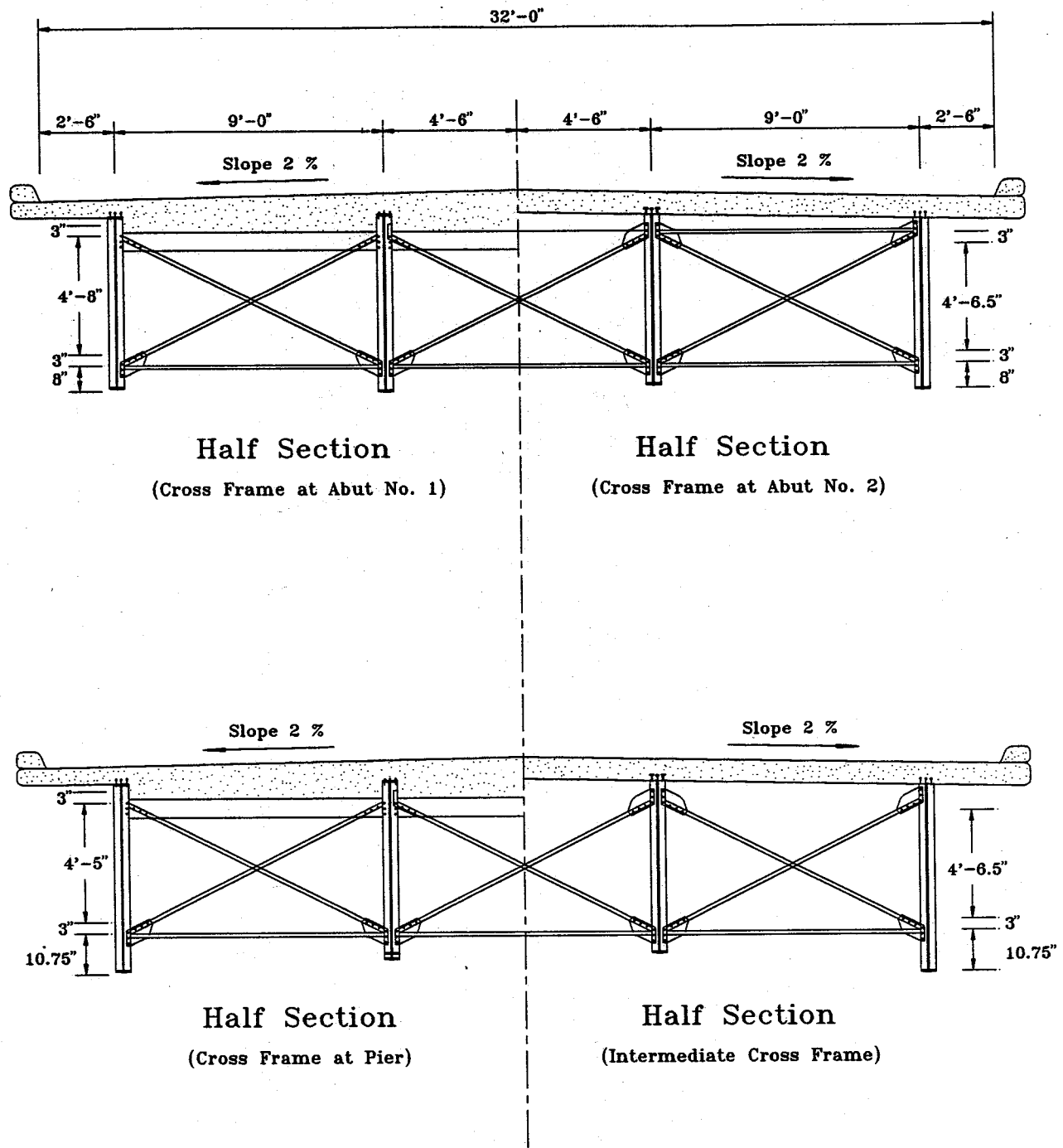


Figure 37. Cross Sections of the Three-Span Continuous Composite Bridge

For Beam/Girder Bridge

DC 1 : 2,1.267

DC 2 :1,1.636,1.636

DC 3.2.1 : 3,29000.

DC 3.2.2 : 5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969, 39.6, 61167.

5.969,39.6,61167.

5.969,47.0,43973.

5.969,47.0,43973.

5.969,47.0,43973.

5.969,47.0,43973.

5.969,47.0,43973.

5.969,47.0,43973.

7.75,47.0,43973.

7.75,47.0,43973.

7.75,47.0,43973.

7.75,47.0,43973.

7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,47.0,43973.
7.75,47.0,43973.
7.75,47.0,43973.
7.75,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

DC 4.1 : 36.

DC 4.1.2.1 : 1160.2,1165.,1160.2

DC 4.1.2.2 : 1160.2,1165.,1160.1

DC 4.1.2.3 : 1160.2,1160.2

DC 4.1.2.4 : 126.,126.

DC 4.1.2.5 : 12.,12.

DC 4.1.2.6 : 74.,73.75,73.75,74.

DC 4.1.2.7 : 0.313,0.313,0.313,0.313

DC 4.1.2.8 : 7.3,7.3

For Fatigue Analysis, only for steel bridges

DC 1 : 5

The Input Data File Is Printed Out As:

Composite Steel Girder Bridge, Three Continuous Spans

1,2,3,3

4,21 2,1,1,1,1,0,1,5000.

2,1.267

1,1.636,1.636

3,29000.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.

5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
7.75,47.0,43973.
7.75,47.0,43973.
7.75,47.0,43973.
7.75,47.0,43973.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,41.1,65220.
7.75,47.0,43973.
7.75,47.0,43973.
7.75,47.0,43973.
7.75,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,47.0,43973.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
5.969,39.6,61167.
36.
1160.2,1165,1160.2
1160.2,1165,1160.1
1160.2,1160.2 126.,12 6.
12.,12.
74.,73.75,73.75,74.
0.313,0.313,0.313,0.313
7.3,7.3
5

The Output Result File Is Given As:

Composite Steel Girder Bridge, Three Continuous Spans

***** NO. 1 RATING VEHICLE: TYPE 3S2 *****

AVERAGE DAILY TRUCK TRAFFIC: 5000.00000 TRUCKS/DAY
 DEAD LOAD FACTOR: 1.20000
 LIVE LOAD FACTOR: 1.45000
 RESISTANCE FACTOR: .75000
 IMPACT FACTOR: .20000
 FATIGUE STRESS CATEGORY: D.
 DEAD LOAD OF BRIDGE: 1.26700 K/FT
 DISTRIBUTION FACTOR' FOR BENDING MOMENT: 1.63660
 DISTRIBUTION FACTOR FOR SHEAR: 1.63600
 MODULUS OF ELASTICITY OF BRIDGE: 29000.00000 KSI
 YIELD STRENGTH OF STEEL: 36.00000 KSI

PLASTIC SECTION MODULUS AT THE MAX. POSITIVE MOMENT POINT

| SPAN | TOP SECTION (IN*IN*IN) | BOTTOM SECTION (IN*IN*IN) |
|------|---------------------------|------------------------------|
| 1 | 1160.20000 | 1160.20000 |
| 2 | 1165.00000 | 1165.00000 |
| 3 | 1160.20000 | 1160.10000 |

SECTION PROPERTIES AT EACH SUPPORT (NEGATIVE MOMENT)

| SUPPORT | DEPTH (IN) | WEB THICKNESS (IN) | RAD. OF GYR. (Y-Y) (IN) |
|---------|---------------|-----------------------|----------------------------|
| 1 | 74.00000 | .31300 | |
| 2 | 73.75000 | .31300 | 7.30000 |
| 3 | 73.75000 | .31300 | 7.30000 |
| 4 | 74.00000 | .31300 | |

| SUPPORT | PLASTIC SEC. MOD. (IN*IN*IN) | UNBRACED LENGTH (IN) | FLANGE WIDTH (IN) |
|---------|---------------------------------|-------------------------|----------------------|
| 2 | 1160.20000 | 126.00000 | 12.00000 |
| 3 | 1160.20000 | 126.00000 | 12.00000 |

| ELE. | LENGTH (FT) | CROSS AREA (IN*IN) | MOMENT OF INERTIA (IN*IN*IN*IN) |
|------|----------------|-----------------------|------------------------------------|
| 1 | 5.96900 | 39.60000 | 61167.00000 |
| 2 | 5.96900 | 39.60000 | 61167.00000 |
| 3 | 5.96900 | 39.60000 | 61167.00000 |
| 4 | 5.96900 | 39.60000 | 61167.00000 |
| 5 | 5.96900 | 39.60000 | 61167.00000 |
| 6 | 5.96900 | 39.60000 | 61167.00000 |
| 7 | 5.96900 | 39.60000 | 61167.00000 |
| 8 | 5.96900 | 39.60000 | 61167.00000 |
| 9 | 5.96900 | 39.60000 | 61167.00000 |
| 10 | 5.96900 | 39.60000 | 61167.00000 |
| 11 | 5.96900 | 47.00000 | 43973.00000 |

| | | | |
|----|---------|----------|-------------|
| 12 | 5.96900 | 47.00000 | 43973.00000 |
| 13 | 5.96900 | 47.00000 | 43973.00000 |
| 14 | 5.96900 | 47.00000 | 43973.00000 |
| 15 | 5.96900 | 47.00000 | 43973.00000 |
| 16 | 5.96900 | 47.00000 | 43973.00000 |
| 17 | 7.75000 | 47.00000 | 43973.00000 |
| 18 | 7.75000 | 47.00000 | 43973.00000 |
| 19 | 7.75000 | 47.00000 | 43973.00000 |
| 20 | 7.75000 | 47.00000 | 43973.00000 |
| 21 | 7.75000 | 41.10000 | 65220.00000 |
| 22 | 7.75000 | 41.10000 | 65220.00000 |
| 23 | 7.75000 | 41.10000 | 65220.00000 |
| 24 | 7.75000 | 41.10000 | 65220.00000 |
| 25 | 7.75000 | 41.10000 | 65220.00000 |
| 26 | 7.75000 | 41.10000 | 65220.00000 |
| 27 | 7.75000 | 41.10000 | 65220.00000 |
| 28 | 7.75000 | 41.10000 | 65220.00000 |
| 29 | 7.75000 | 47.00000 | 43973.00000 |
| 30 | 7.75000 | 47.00000 | 43973.00000 |
| 31 | 7.75000 | 47.00000 | 43973.00000 |
| 32 | 7.75000 | 47.00000 | 43973.00000 |
| 33 | 5.96900 | 47.00000 | 43973.00000 |
| 34 | 5.96900 | 47.00000 | 43973.00000 |
| 35 | 5.96900 | 47.00000 | 43973.00000 |
| 36 | 5.96900 | 47.00000 | 43973.00000 |
| 37 | 5.96900 | 47.00000 | 43973.00000 |
| 38 | 5.96900 | 47.00000 | 43973.00000 |
| 39 | 5.96900 | 39.60000 | 61167.00000 |
| 40 | 5.96900 | 39.60000 | 61167.00000 |
| 41 | 5.96900 | 39.60000 | 61167.00000 |
| 42 | 5.96900 | 39.60000 | 61167.00000 |
| 43 | 5.96900 | 39.60000 | 61167.00000 |
| 44 | 5.96900 | 39.60000 | 61167.00000 |
| 45 | 5.96900 | 39.60000 | 61167.00000 |
| 46 | 5.96900 | 39.60000 | 61167.00000 |
| 47 | 5.96900 | 39.60000 | 61167.00000 |
| 48 | 5.96900 | 39.60000 | 61167.00000 |

THE RATING RESULT FOR CONTINUOUS SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | TYPE 3S2 | 1.14 |
| 2 | TYPE 3S2 | .86 |
| 3 | TYPE 3S2 | 1.14 |

NEGATIVE MOMENT

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 2 | TYPE 3S2 | 4.13 |
| 3 | TYPE 3S2 | 4.13 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | TYPE 3S2 | 4.08 |
| 2 | TYPE 3S2 | 3.08 |
| 3 | TYPE 3S2 | 3.09 |
| 4 | TYPE 3S2 | 4.08 |

THE FATIGUE LIFE FOR CONTINUOUS SPAN BRIDGE

POSITIVE MOMENT

| SPAN | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR-1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|------|-------------------------------------|------------------------------------|-------------------------|
| 1 | 7.06132 | 3 | 51.73209 |
| 2 | 8.11555 | 3 | 45.01196 |
| 3 | 7.25708 | 3 | 50.33658 |

NEGATIVE MOMENT

| SUPPORT | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|---------|-------------------------------------|------------------------------------|-------------------------|
| 1 | 4.84258 | 4 | 56.57577 |
| 2 | 5.23939 | 3 | 69.72129 |

***** NO. 2 RATING VEHICLE: TYPE 3-3 *****

AVERAGE DAILY TRUCK TRAFFIC: 5000.00000 TRUCKS/DAY *

THE RATING RESULT FOR CONTINUOUS SPAN BEAM/GIRDER BRIDGE

POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
|------|----------------|---------------|

| | | |
|---|----------|------|
| 1 | TYPE 3-3 | 1.15 |
| 2 | TYPE 3-3 | .85 |
| 3 | TYPE 3-3 | 1.15 |

NEGATIVE MOMENT

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 2 | TYPE 3-3 | 3.96 |
| 3 | TYPE 3-3 | 3.96 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | TYPE 3-3 | 4.01 |
| 2 | TYPE 3-3 | 2.93 |
| 3 | TYPE 3-3 | 2.94 |
| 4 | TYPE 3-3 | 4.01 |

THE FATIGUE LIFE FOR CONTINUOUS SPAN BRIDGE

POSITIVE MOMENT

| SPAN | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|------|-------------------------------------|------------------------------------|-------------------------|
| 1 | 7.18952 | 3 | 50.80964 |
| 2 | 8.23030 | 3 | 44.38440 |
| 3 | 7.04648 | 3 | 51.84107 |

NEGATIVE MOMENT

| SUPPORT | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|---------|-------------------------------------|------------------------------------|-------------------------|
| 1 | 5.51943 | 3 | 66.18383 |
| 2 | 5.50923 | 3 | 66.30636 |

***** NO. 3 RATING VEHICLE: HS20-44 *****

AVERAGE DAILY TRUCK TRAFFIC: 5000.00000 TRUCKS/DAY

* THE RATING RESULT: FOR CONTINUOUS SPAN BEAM/GIRDER BRIDGE
 POSITIVE MOMENT

| SPAN | RATING VEHICLE | RATING FACTOR |
|------|----------------|---------------|
| 1 | HS20-44 | .97 |
| 2 | HS20-44 | .75 |
| 3 | HS20-44 | .97 |

NEGATIVE MOMENT

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 2 | HS20-44 | 2.71 |
| 3 | HS20-44 | 2.71 |

END SHEAR

| SUPPORT | RATING VEHICLE | RATING FACTOR |
|---------|----------------|---------------|
| 1 | HS20-44 | 3.55 |
| 2 | HS20-44 | 2.73 |
| 3 | HS20-44 | 2.73 |
| 4 | HS20-44 | 3.55 |

THE FATIGUE LIFE FOR CONTINUOUS SPAN BRIDGE POSITIVE MOMENT

| SPAN | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|------|-------------------------------------|------------------------------------|-------------------------|
| 1 | 8.38966 | 3 | 43.54133 |
| 2 | 9.32175 | 3 | 39.18757 |
| 3 | 8.47945 | 3 | 43.08026 |

NEGATIVE MOMENT

| SUPPORT | EQUIVALENT STRESS RANGE (KSI) | NUMBER OF CYCLES FOR 1 TRUCK(S) | FATIGUE LIFE (YEARS) |
|---------|-------------------------------------|------------------------------------|-------------------------|
| 1 | 5.28868 | 4 | 51.80358 |
| 2 | 5.54794 | 3 | 65.84373 |

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This computer package can rate the bridge capacity in beam/girder, longitudinal deck/slab, and transverse deck/slab bridges according to new AASHTO specifications [2]. In addition, it can predict the fatigue life of steel bridges based on the standard H or HS truck loadings, Type 3, Type 3S2, and Type 3-3 truck loadings, and equivalent lane loadings. Both simple and continuous span bridges were dealt with in the package. The materials of the bridges can be steel, reinforced concrete, or timber. Either uniform or nonuniform cross section of bridge can be utilized. The data obtained from output results can be used to plot the diagrams of influence line and envelope for shear and moment by using the special program BRAF-P contained in the package without any modification or any plotting software. Also, the bending stress history of any critical joint can be plotted to determine the equivalent stress range.

This package can run on IBM PC/XT, AT, or above computers, and compatibles. It can also be used in the general main frame computers. The package, combining capacity rating and prediction of the remaining service life of highway bridges, will provide the U.S. industries a constructive tool in evaluating the numerous existing highway bridges. Furthermore, it is applicable in bridge design course for educational purposes.

Finally, some suggestions could be made for this computer package in its further improvement. First, more types of bridge, which can be rated by using the package, should be included, such as box girder, prestressed concrete, slant-legged, and truss bridges, etc. Second,

in order to obtain more accurate and comprehensive results in bridge rating and fatigue life analysis, a three-dimensional structural analysis should be carried out instead of a one dimensional structural analysis in conjunction with the distribution of loads in the present package. Further research is necessary in these areas. However, the computer system developed in this study would be useful in highway bridge rating and fatigue life prediction.

APPENDIX A

USER'S MANUAL OF BRAF PROGRAM

A.1 General

This program can be used to compute the rating factor based on the new AASHTO specifications for deck, slab, beam, stringer, and girder members in highway bridges. This program can also be used to compute the fatigue life for steel bridges. The types of bridges are simple uniform beams or continuous beams.

The materials of each bridge member can be timber, reinforced concrete, or steel. Single truck was used to determine the fatigue life. Following are the most significant limitations of the program

Maximum number of nodes = 113

Maximum number of spans = 7

Maximum number of elements = 112

Maximum number of DOF's = 328

Highway Bridge Rating and Fatigue Program (BRAf) was developed in FORTRAN Language and compiled by Microsoft FORTRAN Compiler 5.1. It can be run on IBM PC XT, AT, or above computers, and compatible computers.

The characteristics of the program are listed below:

- a. All real variables = REAL*4.
- b. Use graphic mode for screen printing.
- c. Use input/output skill to reduce the size of the bridge stiffness matrix.
- d. Store the bridge stiffness matrix in the disk in order to save computer memory storage (unformatted data).
- e. Define the number of joint from left support to right support in sequence.
- f. In addition to the, input data file and the output data file, another four files are, opened to print out or plot the bending stress history for maximum positive and negative, moment, the shear influence lines, the moment influence lines, and the shear and moment envelopes by using another program which will be described later.

A.2 How To Run BRAF Program

It is very simple to run BRAF program just by typing “BRAf” and then names of the input data file and the output data files from the keyboard in dialogue way. The names of six input/output data files are recommended for ease of identification as follows:

BRAF.I** : Input data file

BRAF.O** : Output data file to store the results of the analysis

BRAF.P** : Output data file for plotting the bending stress histories

BRAF.S** : Output data file for plotting the shear influence lines

BRAF.M** : Output data file for plotting the moment influence lines

BRAF.E**: Output data file for plotting the shear and moment envelopes

A.3 Preparation of Data File

The input data file (e.g., BRAF.I**) for abridge rating and fatigue life analysis should be prepared before running BRAF program. All data for the analysis will be read from the file in the sequential access method. The data will be described one Data Code (DC) after another as below.

Part I: Control Information

Part II: For Girder Bridges

Part III: For longitudinal concrete deck (slab)

Part IV: For transverse deck (slab) bridges

Part V: Fatigue Analysis, only for steel bridges

Part I: Control Information

DC 1: TITLE

Any ASCII codes not exceeding 80 characters for the user's convenience in recording a title of pertinent information about- this rating or/and fatigue analysis.

DC 2: IGD, IRF, ME, NLOAD

IGD = Index of girder or deck bridges

- 1: For beam/girder bridges
- 2: For longitudinal concrete deck (slab)
- 3: For transverse deck (slab)

IRF = Index of rating and fatigue

- 1: For rating analysis only
- 2: For rating and fatigue analyses

IIE = Index for printing the shear and moment influence lines and/or envelopes

- 1: For printing influence lines
- 2: For printing envelopes
- 3: For printing both influence lines and envelopes
- 0: For no printing influence lines and envelopes

NLOAD = Number of rating vehicle load types

DC 3: (ITRUCK(I), I=1, NLOAD)

ITRUCK = Index of truck loading

- 1: For Type 3
- 2: For Type 3S2
- 3: For Type 3-3
- 4: For HS20-44

5: For HS 15-44

6: For H20-44

7: For H15-44

8: For special load

DC 3.1: NA(8), only for special load, i.e., ITRUCK(I)=8

NA(8) = Number of the axles. The maximum number of the axles is 10.

DC 3.2: (SPTL(I), I=1, NA(8)), only for ITRUCK(I)=8

SPTL(1) = Axle Loads.

DC 3.3: (SPTLS(I), I=1, (NA(8)-1)), only for ITRUCK(I)=8

SPTLS(I) = Spacing between the axles.

DC 4: IMP, IRED, IDET, INSP, MAINT, IDLF, ITRA, ADTT

IMP = Index of impact factor

1: For good and fair condition

2: For poor condition

3: For critical condition

IRED = Index of redundancy

0: For non-redundancy

1: For redundancy

IDET = Index of deterioration

0: For no deterioration

1: For some deterioration

2: For heavy deterioration

INSP = Index of inspection

1: For estimated inspection

2: For careful inspection

MAINT = Type of maintenance

1: For intermittent maintenance

2: For vigorous maintenance

IDLF = Index of dead load factor

0: For nominal thickness of deck (exclude the overlay thickness)

1: For actual thickness of deck (include the overlay thickness)

ITRA = Index of traffic condition

1: For reasonable enforcement and apparent control of overloads

2: For significant sources of overloads without effective enforcement

ADTT = Average daily truck traffic

Part II: For Girder Bridges. i.e., IGD=1

DC 1: IB, UW

IB = Index of bridge

1: For simply supported bridges

2: For continuous bridges

UM = Average unit weight of beam (kip/ft)

DC 2: IG, DISM, DISV

IG = Index of girder materials

1: For steel

2: For reinforced concrete

3: For timber

DISM = Distribution factor for moment

DISV = Distribution factor for shear

DC 3.1:1: BL, only for simple supported bridges, i.e., IB=1

BL = Bridge length for simple supported bridge (ft)

DC 3.2.1: NS, E, only for continuous beam bridges, i.e., IB=2

NS = Number of spans

E = Modulus of elasticity (ksi)

DC 3.2.2: (XLEN(I), XAREA(n), ZZIM, I=1, NE), only for IB=2

XLEN(I) = Element length (ft)

XAREA(I) = Cross section area of element (in²)

ZZI(I) = Cross section moment of inertia of element (in⁴)

NE = (Number of spans) * 16

DC 4.1: FY1, only for steel girders, i.e., IG = 1

FY1 = F_y, yield stress (ksi)

DC 4.1.1.1: PSMT1(1), PSMB1(1), DDI(1), TW(1), only, for simple supported bridges, i.e.,

IB = 1

PSMT1(1) = Plastic section modulus for top section (in)

PSMB1(1) = Plastic section modulus for bottom; section (in)

DDI(1) = Depth of beam (in)

TW(1) = t_w, web thickness of beam (in)

DC 4.1.2.1: (PSMT1(I), I=1, NS), only for continuous beam bridges, i.e., IB = 2

PSMTI(I) = Plastic section modulus for top section at each middle span (for positive moment area)
(in³)

DC 4.1.2.2: (PSMB1(I), I=1, NS), only for IB=2

PSMB1(I) = Plastic section modulus for bottom section at each middle span (for positive

moment) (in³)

DC 4.1.2.3: (PSMNI(I), I=1, (NS-1)), only for IB=2

PSMNI(I) = Plastic section modulus for bottom section at each support (for negative moment area) (in)

DC 4.1.2.4: (AL(I), I=1, (NS-1)), only for IB=2

AL(I) = Lateral unbraced length in compression side of beam (for negative moment area) (in)

DC 4.1.2.5: (BBI(I), I=1, (NS-1)), only for IB = 2

BBI(I) = Flange width in compression section (bottom) of beam/girder (for negative moment area) (in)

DC 4.1.2.6: (DD1(I), I=1, (NS+1)), only for IB = 2

DD1(I) = Depth of beam at each support (in)

DC 4.1.2.7: (TW(I), I=1, (NS+1)), only for IB = 2

TW(I) -- Web thickness of beam at each support (in)

DC 4.1.2.8: (RY(I), I=1, (NS-1)), only for IB = 2

RY(I) = Radius of gyration with respect to Y-Y (transverse) axis (in)

DC 4.2: IS, FC2, FY2 only for concrete girders, i.e., IG=2

IS = Index of section

1: For rectangular section

2: For T section

FC2 = f'_c , ultimate concrete compressive strength (ksi)

FY2 = f_y , yield strength of reinforcement (ksi)

DC 4.2.1.1: BB2(1), DD2(1), AS(1), only for simply supported beam and rectangular section, i.e., IB=1 and IS =1

BB2(1) = Width of rectangular cross section (in)

DD2(1) = d , depth of T section (positive, moment) (in)

AS(1) = A_s , the area of reinforcement (positive moment) (in^2)

DC 4.2.1.2: BF(1), BW(1), HF(1), DD2(1), AS(1), only for simply supported beam and T-section, i.e., IB=1 and IS=2

BF(1) = B_f , flange width of T cross section (in)

BW(1) = b_w , web width of cross section (in)

HF(1) = h_f , thickness of flange of T cross section (in)

DD2(1) = d , depth of T section (positive moment) (in)

AS(1) = A_s , the area of reinforcement (positive moment) (in^2)

DC 4.2.2.1.1: (BB2(I), I=1, NS), only for continuous beam and rectangular section, i.e., IB=2 and IS=1

BB2(I) = Width of rectangular, cross, section for, each span (in)

DC 4.2.2.1.2: (DD2(I), I=1, NS), only for IB=2 and IS=1

DD2(I) = d, depth of T section for each span (positive moment) (in)

DC 4.2.2.1.3: (DDN(I), I=1, (NS-1)), only for IB=2 and IS=1

DDN(I) = d', the distance from the center of reinforcement to the bottom of section for each intermediate support (negative moment) (in)

DC 4.2.2.1.4: (AS(I) I=1, NS), only for IB=2 and IS=1

AS (I) = A_s, the area of T section at each middle span (positive moment) (in²)

DC 4.2.2.1.5: (ASN(I), I=1, (NS-1)), only for IB=2 and IS=1

ASN(I) = A_s', the cross sectional area of reinforcement at each intermediate supports (negative moment) (in²)

DC 4.2.2.2.1: (BF(I), I=1, NS), only for continuous beam and T-section, i.e., IB=2 and IS=2

BF(I) = B_f, flange width of T cross section for each span (in)

DC 4.2.2.2.2: (BW(I), I=1, NS), only, for IB = 2 and IS=2

BW(I) = b_w, web width of T cross section for each span (in)

DC 4.2.2.2.3: (HF(I), I=1, NS), only for IB=2 and IS=2

HF(I) = h_f, thickness of-flange of T cross section for each span (in)

DC 4.2.2.2.4: DD2(I), only for IB=2 and IS=2

DD2(I) = d, depth of T section for each span (positive moment) (in)

DC 4.2.2.2.5: (DDN(I), I=1, (NS-1)) only for IB=2 and IS=2 ,

DDN(I) = d', the distance from the center of reinforcement to the bottom of T section for each intermediate support (negative moment) (in)

DC 4.2.2.2.6: (AS(I), I=1, NS), only for IB=2 and IS=2

AS(I) = A_s , the area of T section for each span (positive moment) (in²)

DC 4.2.2.2.7: (ASN(I), I=1, (NS-1)), only for IB=2 and IS=2

ASN(I) = A_s' , the cross sectional area of reinforcement at each intermediate support (negative moment) (in)

DC 4.3.1: FB, only for timber girder, i.e., IG=3

FB = f_b , allowable bending stress (ksi)

DC 4.3.2.1.1: SM3(1), only for timber and simple girder, i.e., IG=3 and IB=1

SM3(1) = Section modulus of timber girder (positive moment) (in³)

DC 4.3.2.2.1: (SM3(I), I=1, NS), only for timber and continuous; girder, IG=3 and IB =2

SM3(I) = Section modulus of timber girder for each span (positive moment) (in³)

DC 4.3.2.2.2: (SMN3(I), I=1, NS), only for IG=3 and IB=2

SMN3(I) = Section modulus of timber girder for each span (positive moment) (in^3)

Part III: For longitudinal concrete deck (slab): i.e., IGD=2

DC 1: IB, UW

IB = Index of bridge

1: For simple bridges

2: For continuous beam bridges

UM = Average unit weight of beam (k/ft)

DC 2: DW

DW = Distribution width (ft)

DC 3.1.1: BL, only for simply supported bridges, i.e., IB=1

BL = Bridge length for simple bridge (ft)

DC 3.2.1: NS, E, only for continuous beam bridges, i.e., IB=2

NS = Number of spans

E = Modulus of elasticity (ksi)

DC 3.2.2: (XLEN(I), XAREA(I), ZZI(I), I=1, NE) only for IB=2

$XLEN(I)$ = Element length (ft)

$XAREAM$ = Cross section area of element (in^2)

$ZZI(I)$ = Cross section moment of inertia of element (in^4)

NE = (Number of spans) * 16

DC 4: FC6, FY6

$FC6 = f'_c$, ultimate concrete compressive strength (ksi)

$FY6 = f_y$, yield strength of reinforcement (ksi)

DC 5.1.1: DD6(1), AS(6), only for simple bridges, i.e., IB=1

$DD6(1) = d$, the distance from the center of reinforcement to the bottom of section (in)

$AS(6) = A_s$, the area of reinforcement for each span (positive moment) (in^2)

DC 5.2.1: (DD6(I), I=1 NS), only for continuous bridges, i.e., IB=2

$DD6(I) = d$, the distance from the center of reinforcement to the top of section (in)

DC 5.2.2: (DDN6(1), 1=1, (NS-1)), only for IB=2

$DDN6(I) = d'$, the distance from the center of reinforcement to the bottom of section at each intermediate support (negative moment) (in)

DC 5.2.3: (AS(I), 1=1, NS), only for IB=2

$AS(I) = A_s$, the area of reinforcement for each span (positive moment) (in^2)

DC 5.2.4: (ASN(I), I=1, (NS-1)), only for IB=2

ASN(I) = A_s' , the area of reinforcement at each intermediate support (negative moment) (in²)

Part IV: For transverse deck (slab) bridges: i.e., IGD=3

DC 1: IDM

IDM = Index of transverse deck materials

1: For concrete

2: For timber

DC 2.1.1: ID, FC4, FY4, only for concrete deck (slab), i.e., IDM=1

ID = Index of transverse deck

1: For simple span

2: For continuous

FC4 = f_c' , the ultimate strength of concrete (ksi)

FY4 = f_y , the yield strength of reinforcement (ksi)

DC 2.1.2: SG4, BB4, HD4, DD4, AS4, only for concrete deck

SG4 = Center to Center stringer spacing (transverse concrete deck)

BB4 = Flange width of stringer (transverse concrete deck)

HD4 = Thickness of deck (transverse- concrete deck)

DD4 = Depth of deck (transverse concrete deck)

AS4 = The area of reinforcement per one feet (transverse concrete deck)

DC 2.1.3: ISM, HS, only for concrete deck

ISM = Index of stringer materials

1: For reinforced concrete

2: For steel

3: For timber

HS = Depth of stringer (transverse concrete deck) (in)

DC 2.2.1: ID, FB5, only for timber slab, i.e., IDM=2

ID = Index of transverse deck

1: For simple span

2: For continuous

FB5 = f_b , the yield stress of timber (ksi)

DC 2.2.2: SG5, BB5, HD5, SS, only for timber slab

SG5 = Center to Center stringer spacing (transverse timber deck) (in)

BB5 = flange width of stringer (transverse timber deck) (in)

HD5 = Thickness of deck (transverse timber deck) (in)

SS = Section modulus of cross section (in^3)

Part V: For Fatigue Analysis, only for steel bridges

DC 1: IC

IC = Index of fatigue category

- 1: For category A
- 2: For category B
- 3: For category C (Stiffeners)
- 4: For category C' (Other Attachments)
- 5: For category D
- 6: For category E
- 7: For category F

APPENDIX B

USER'S MANUAL OF BRAF-P PROGRAM

B.1 General

This program (BRAFP) was developed for processing the four output data files (BRAFP**, BRAFS**, BRAFM**, and BRAFE**), which were produced after running BRAF to make a bridge rating and fatigue life analysis. The bending stress histories, shear influence lines, moment influence lines, and the shear and moment envelopes can be plotted, individually. The BRAFP program was written in Microsoft FORTRAN language, Version 5.1 and can run on IBM PC/XT, AT and above computers, or compatible computers.

B.2 How To Run BRAFP Program

The BRAFP program is run on a computer in dialogue way. When you run BRAFP, a menu will be displayed on the screen and a choice should be made for the type of figure you are interested in. The user needs to input the data required for plotting the figure, i.e., answer the question on display. The input data in dialogue are very simple. They are, for example, the number of the loading, the number of joints you are interested in, the number of the figure in accordance with the numbering of the figures in your report, and the name of the related data file which was produced after running the BRAFP program, etc.

After inputting all the data for the plotting, the figure will be displayed on screen and can be copied to a printer in graphics mode by pressing the PRINT SCREEN Key on the keyboard. If you are not interested in the figure, you can return to the menu by simply pressing the ENTER Key and then start a new job or quit the program.

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1. The first part of the document discusses the importance of maintaining accurate records of all transactions.

2. It also emphasizes the need for regular audits to ensure the integrity of the data.

3. Furthermore, the document highlights the role of technology in streamlining the accounting process.

4. The author also discusses the challenges of managing financial data in a complex and ever-changing environment.

5. Finally, the document concludes by offering practical advice on how to overcome these challenges and achieve financial success.

6. The author also discusses the importance of staying up-to-date on the latest trends and technologies in the field.

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