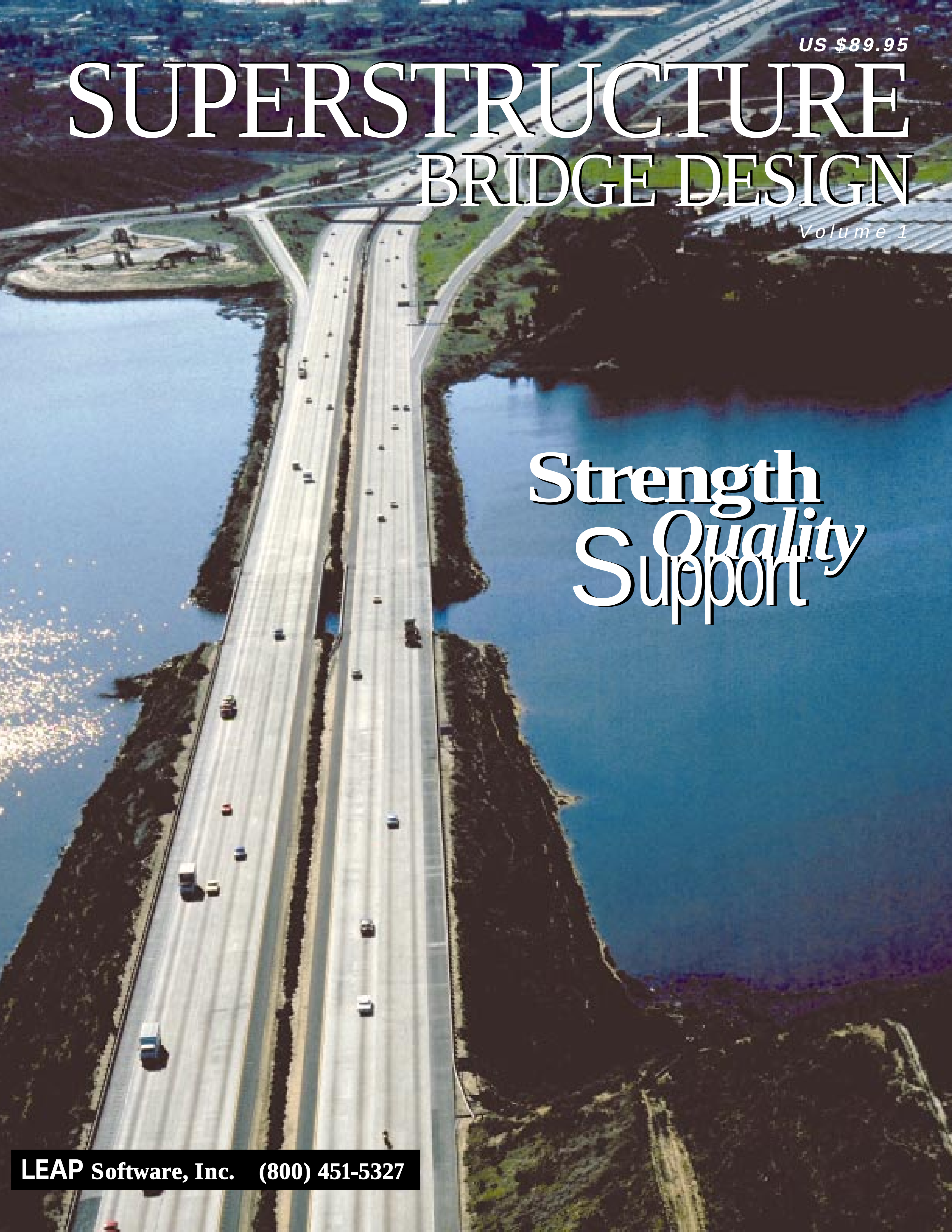
US $89.95

SUPERSTRUCTURE
BRIDGE DESIGN

Volume 1



Strength

Quality

Support

LEAP Software, Inc. (800) 451-5327

Superstructure Bridge Design

Practical AASHTO LFD and LRFD

Superstructure Design Examples for Bridge Engineers

The primary objective of this book is to provide a number of practical design examples and basic concepts for design of precast/prestressed concrete bridge superstructures. This book is unique in the approach it takes, reflecting the belief that traditional, off-the-shelf publications often do not provide the in-depth information necessary to satisfy the needs of practicing engineers.

In satisfying these needs, the book contains five complete examples of typical design calculations for different types of prestressed/precast concrete bridge girders. The design examples cover both single and continuous girder designs. Two examples are in accordance with the AASHTO LRFD Specifications, while three examples are in accordance with the AASHTO Standard (LFD) Specifications.

The Introduction Section includes a unique and valuable collection of topics providing insight into practical design/planning issues. Some of the topics discussed are:

- Preliminary Design (Type, Size, and Location)
- Rehabilitation
- Staged Construction
- Bridge Replacement
- New Construction
- General Design Features

The Theory Section concentrates on design aspects specific to precast/prestressed bridge beam and girder design. Separate sections for the AASHTO LRFD Bridge Design Specifications and the AASHTO Standard (LFD) Specifications are provided.

The Hand Calculations Section contains an in-depth set of calculations for the critical design issues related to ultimate moment, service load criteria, and vertical shear. Other topics include prestress losses, cambers and deflections, and horizontal shear. The AASHTO Code Referencing of equations are also included. Three design examples are illustrated using the AASHTO Standard (LFD) Bridge Specifications along with two design examples using the AASHTO LRFD Specifications.

This book is the result of many years of practical engineering design. We hope it will become a trusted companion for all bridge structural engineers.

TABLE OF CONTENTS

At a glance...

ELASTIC SHORTENING

Same as LFD

Loss of prestress due to elastic shortening is a consequence of elastic shortening of a girder after release. When transformed section properties are used, the loss of prestress due to elastic shortening does not have to be evaluated explicitly since the equations for evaluation of stress already includes the effect of elastic shortening. This is because the area and moment of inertia of the beam includes the transformed steel.

TRANSFER AND DEVELOPMENT LENGTH

The transfer length is the distance required to transfer the force in the strand, under service loads, from a value of 0% at the end of the beam (or end of debonding, if present) to 100% of its capacity. For locations within this region, a linear interpolation is typically performed to compute the effective area of prestressing strand.

The basic transfer length is 60 d_b, as per **Art. 5.11.4.1**. The development length is the distance required to develop the design strength of the strand and is used for ultimate capacity calculations under factored loads. Since the stress under factored loads is higher, the development length is longer than the transfer length. For locations between transfer length and development length, a parabolic interpolation maybe assumed to compute the effective area of steel as per **Art. 5.11.4.1**. A linear interpolation can also be assumed to further simplify computations. Development length as per **Art. 5.11.4.2** is:

US Units $1_d \geq (f_{ps} - 0.6667 f_{pe}) d_b$

Metric Units $1_d \geq (0.15 f_{ps} - 0.097 f_{pe}) d_b$

where:

d_b	=	Nominal strand diameter, in (mm)
f_{ps}	=	Average stress in prestressing steel at time for which nominal resistance of a member is required, ksi (MPa)
f_{pe}	=	Effective stress in prestressing steel after losses, ksi (MPa)

The development length multiplier for debonded strands is 2.0 per **Art. 5.11.4.3**. Readers are encouraged to obtain a copy of the Federal Highway Administration Memorandum dated October 26, 1988 regarding “Prestressing Strand for Pretension Applications - Development Length Revisited”. This memorandum states that the “Development length for all strand sizes up to and including 9/16 inch special strand shall be determined as 1.6 times AASHTO Equation 9-32.” See also FHWA publication number FHWA-RD-98-116 for additional research literature (**Ref. 6**).

DISTRIBUTION OF LOADS

Same as LRFD

TOPPING WEIGHT

The weight of the cast-in-place deck/topping is calculated for the tributary width of each beam. For an interior beam, the tributary width is calculated as half of the distance to the CL of the beams on each side of the beam under consideration. For an exterior beam, the tributary width extends from the edge of the bridge to half of the distance of the next beam, see Figure TH-4 on page 16.

Note that the tributary width should not be confused with the effective width, which is the width of the slab used to calculate the composite section properties.

DEAD LOAD ON COMPOSITE

Same as LRFD

If the composite dead loads (e.g. FWS) are analyzed as area loads, then the area load is multiplied by the overall width of the bridge or face to face of barriers to obtain the total dead load acting on the bridge. Then, a continuous beam analysis is performed to compute moments and shears along the span. The proportionate share of moment and shear distributed to each beam is then computed as follows:

$$DL - Comp\ Trib\ Frac = \frac{B_{Trib}}{Overall\ Width}$$

where:

$DL - Comp\ Trib\ Frac$	=	tributary fraction for dead load on composite
B_{Trib}	=	tributary width of beam under consideration
Overall Width	=	out-to-out width of the bridge.

Art. 3.23.2.3.1.1 allows (but does not require) curbs, railings, and wearing surface to be distributed equally to all roadway stringers or beams if they are placed after the slab has cured. To specify this, the value of the dead load tributary fraction would be equal to 1/(number of beams).

Design Example #1 Multi-Span Bulb Tee Girder Design (LRFD)

NU-1600 GIRDERS

This design example is an example of a continuous three-span bridge with NU-1600 girders with no skew. Diagrams and hand calculations are included in this section. It demonstrates the design of 30000, 33000 and 30000 mm NU-1600 beam bridge, as shown in Figure DE1-5.

This example illustrates in detail the design of a typical interior beam of the center span at the critical sections in positive flexure, negative flexure, shear, and deflection due to prestress, dead loads, and live loads. The superstructure consists of four NU-1600 beams spaced at 3600 mm centers, as shown in Figure DE1-2. Beams are designed to act compositely with the 200 mm cast-in-place concrete slab to resist all superimposed dead loads, live loads, and impact. A 10 mm wearing surface is considered to be an integral part of the 200 mm slab. Design live load will be AASHTO LRFD HL-93. The design will be carried out in accordance with “AASHTO LRFD Bridge Design Specifications,” Second Edition, 1998, including the 1999 Interims.

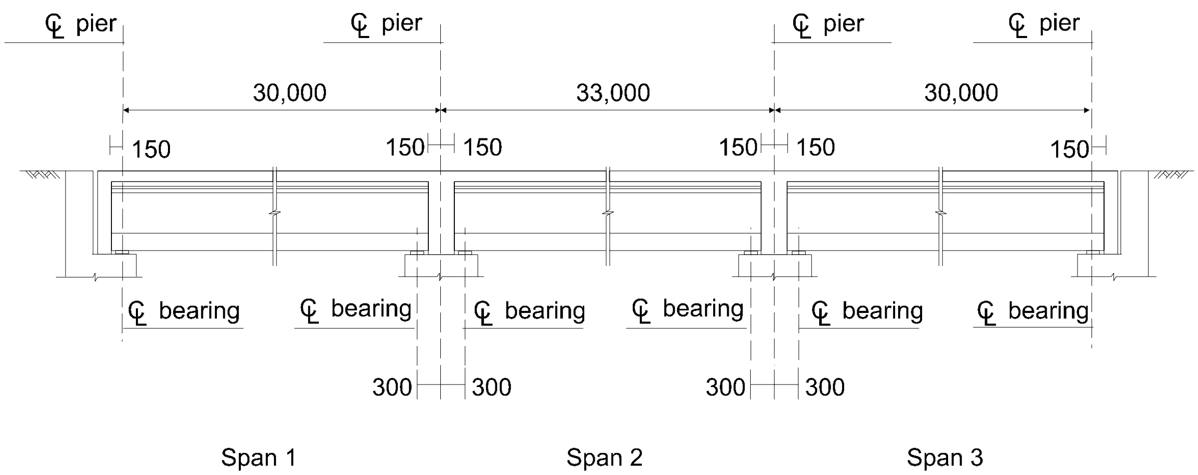


FIGURE DE1-1. Elevation (all dimensions are in mm.)

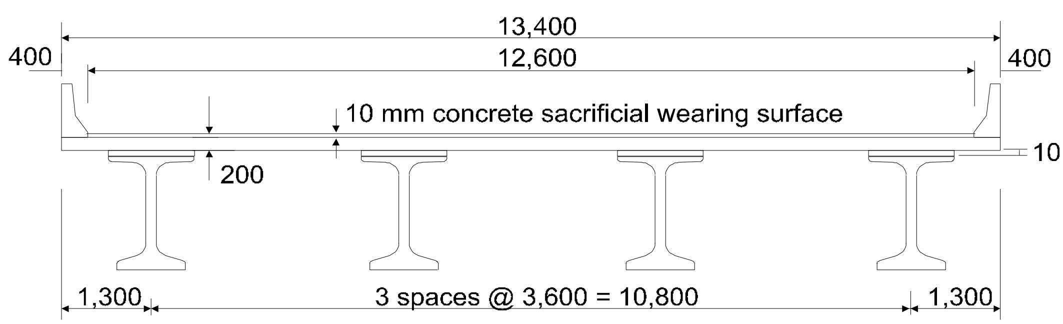


FIGURE DE1-2. Bridge Cross Section (all dimensions are in mm.)

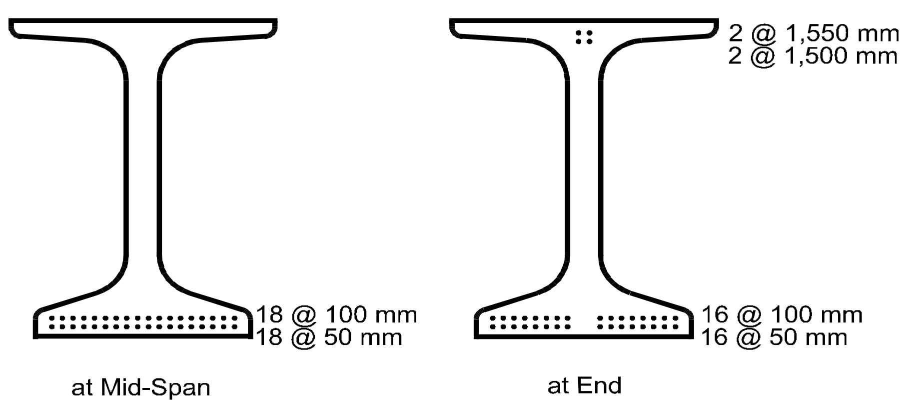


FIGURE DE1-3. Strand Pattern (Span 2, Beam 2)

PRESTRESS LOSSES

Art. 5.9.5

Total prestress losses:

$\Delta f_{pT} = \Delta f_{pES} + \Delta f_{pSR} + f_{pCR} + f_{pR2}$

Eq. 5.9.5.1-1

where:

Δf_{pES} = loss due to elastic shortening

Δf_{pCR} = loss due to creep

Δf_{pSR} = loss due to shrinkage

Δf_{pR2} = loss due to relaxation of steel after transfer

ELASTIC SHORTENING

$$\Delta f_{pES} = \frac{E_p}{E_{ci}} f_{cgp}$$

Art. 5.9.5.2.3a

Eq. 5.9.5.2.3a-1

where:

E_p = modulus of elasticity of prestressing reinforcement

= 197000 MPa

E_{ci} = modulus of elasticity of beam at release

= 29966 MPa

f_{cgp} = sum of concrete stresses at the center of gravity of prestressing tendons due to prestressing force at transfer and the self-weight of the member at sections of maximum moment

where:

Force per strand immediately after transfer:

= (*area of strand*) (*prestress after transfer*)

= (98.7)(0.70)(1861.6 MPa)

= 128,628 N

NOTE: Art. 5.9.5.2.3 states that "…f_{cgp} may be calculated on the basis of a prestressing steel stress assumed to be 0.65 f_{pu} for stress-relieved strands and 0.70 f_{pu} for low-relaxation strands".

P_i = Total prestressing force at release

= (36 *strands*)(128628)

= $\underline{\underline{4{,}630{,}642 \text{ N}}}$

Design Example #4 Multi-Span Bulb Tee Girder Design (LFD)

72" BULB TEE AND CONTINUITY DESIGN

Design Example #4 is a continuous three-span bridge with Bulb Tee Girders and Continuity Design. Diagrams and hand calculations are included in this section. An interior beam in the end span (Span 1) will be designed.

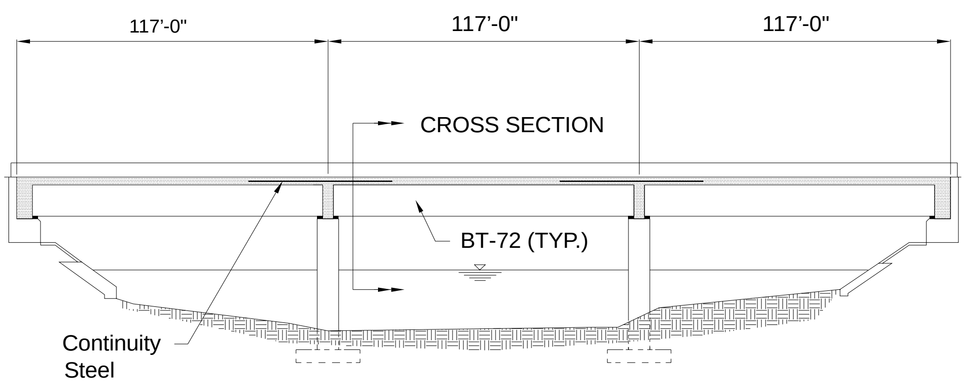


FIGURE DE4-1. Elevation View

The weights of the barriers and the future wearing surface are assumed to be equally divided among girders.

HORIZONTAL SHEAR

AT H/2 As for Vertical Shear, section in right half controls:

V_u = total factored shear force
= $1.3\,[(SW + DL_{prec} + \text{Top} + DL_{comp}) + 1.67(LL)]$
= 1.3 [(43.26 k) + (9.75 k) + (47.21 k)
+ (17.10 k) + 1.67(80.70)]
= 328.1 k

$$V_{nh} \geq \frac{V_u}{\phi} = \frac{328.1\text{ k}}{0.90} = 364.6\text{ k}$$

CASE (A): ***Contact surface is roughened.***

V_{nh} = $80 b_v d$ **Art. 9.20.4.3(a)**

$$= \frac{(80)(42)(76.25)}{1000} = 256.2\text{ k} < 364.6\text{ k} \quad \textbf{NG}$$

CASE (B): ***Minimum ties provided, contact surface not roughened.***

V_{nh} = $80 b_v d$ = 256.2 k **Art. 9.20.4.3(b)**

$$A_{vhmin} = \frac{50 b_v s}{f_y} = \frac{50(42)(12)}{60{,}000} = 0.42\ \text{in}^2/\text{ft}$$ **Art. 9.20.4.5(a)**

If 0.42 in²/ft of steel is provided, capacity of unroughened surface is 256.2 k. Therefore, additional steel must be provided to increase capacity. For each percent of tie reinforcement crossing the contact surface in excess of minimum, V_{nh} may be increased by:

$$\left(\frac{160 f_y}{40{,}000}\right) b_v d$$

Surf = (12)(42) = 504.0 in²/ft
1% = (.01)(504.0) = 5.04 in²/ft

Consequently, if 5.04 in² of steel are provided, additional capacity is:

$$= \frac{\left[\frac{(160)(60{,}000)}{40{,}000}\right](42)(76.50)}{1000} = 771.1\text{ k}$$

Additional capacity needed:
364.6 k - 256.2 k = 108.4 k