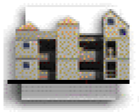


CHAPTER 2: Structural Steel Beams

2.2 Shear Capacity of Welded Studs

Discussion

Shear studs are welded to the top flange of a steel beam to connect the beam to a concrete slab, forming a composite section. The composite section is stronger and stiffer than a steel beam of the same size that is not connected to the slab with shear studs. The slabs may be either a solid concrete, concrete placed on permanent steel forms or a composite section consisting of concrete and a composite steel deck.

The shear strength of the studs depends on the diameter and length, the strength and weight of the concrete, and the orientation and profile of permanent steel forms or composite steel decks, if used.

The strength of a stud is first calculated in a solid or flat soffit slab of normal weight concrete, and then strength reduction factors are applied for the use of lightweight concrete, and for the profile and orientation of steel forms or composite steel decks. The AISC Specification Section I4 presents formulas and tables for calculating shear stud capacity and the reduction factors.

This application calculates the shear capacity of 1/2", 5/8", 3/4" and 7/8"-diameter welded studs in a flat soffit slab of normal weight concrete, the reduction factors for lightweight concrete and for the profile and orientation of steel forms or composite steel decks, and the shear capacity of the studs with the reduction factors applied. Linear interpolation is used for any intermediate values of concrete strength and weight that do not match the tabulated values in the AISC Manual.

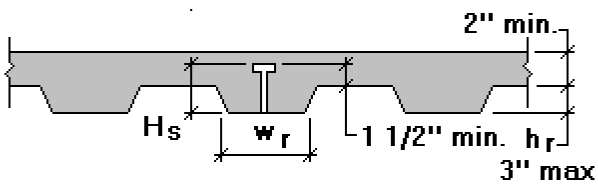
The user must enter the compressive strength and unit weight of concrete, stud diameter and length, and the rib height, rib width and number of studs per rib for steel forms or decks.

A summary of input and computed values is shown on pages 7-9.

Reference: AISC "Specification for Structural Steel Buildings -- Allowable Stress Design and Plastic Design with Commentary." June 1, 1989

Input

Notation



Input Variables

Enter compressive strength of concrete, unit weight of concrete, stud diameter, steel deck rib height and width, and number of studs per rib.

Specified compressive strength of concrete:	$f'_c := 3750 \cdot psi$
Unit weight of concrete (minimum weight of 90 pcf):	$w_c := 107 \cdot pcf$
Stud diameter, not to exceed 3/4" for formed steel decks:	$\phi := \frac{3}{4} \cdot in$
Nominal rib height, 0" for flat soffit slabs:	$h_r := 3 \cdot in$
Length of stud connector after welding, (not to exceed h_r + 3" in computations):	$H_s := 4.5 \cdot in$
Number of shear connectors on beam in one rib, (not to exceed 3 in computations):	$N_r := 3$

Average width of concrete rib or haunch: $w_r := 10.5 \cdot in$

Computed Variables

The following variables are calculated in this document:

C_L capacity reduction factor for lightweight concrete, (w_C between 90 and 120 pcf)

C_T capacity reduction factor for formed steel deck ribs transverse to beam span

C_P capacity reduction factor for formed steel deck ribs parallel to beam span

q_N allowable shear load per stud for solid slab of normal weight concrete

q allowable shear load per stud for solid slabs

q_T allowable shear load per stud with formed steel deck transverse to beam span

q_P allowable shear load per stud with formed steel deck parallel to beam span

Defined Units

$pcf := lb \cdot ft^{-3}$

Calculations

Allowable horizontal shear load for one connector in a solid slab of normal weight concrete q_N

The allowable shear load for studs is shown in AISC Specification, Table I4.1, for concrete strengths of 3, 3.5 and 4 ksi or greater. This application interpolates Table I4.1 to obtain the allowable connector shear load for any specified concrete strength greater than or equal to 3 ksi.

Four element vectors k are defined for each stud diameter, with elements k_0 and k_3 equal to the stud capacities at the lower and higher concrete strengths for the range being interpolated, element k_1 equal to the difference in stud capacities between the higher and lower concrete strengths, and element k_2 equal to the lower concrete strength.

$$k := \text{if}\left(\phi = \frac{1}{2}\cdot in, \begin{bmatrix} 5.1 \\ 0.8 \\ 3 \\ 5.9 \end{bmatrix}, \text{if}\left(\phi = \frac{5}{8}\cdot in, \begin{bmatrix} 8 \\ 1.2 \\ 3 \\ 9.2 \end{bmatrix}, \text{if}\left(\phi = \frac{3}{4}\cdot in, \text{if}\left(f'_c \le 3.5\cdot ksi, \begin{bmatrix} 11.5 \\ 1 \\ 3 \\ 13.3 \end{bmatrix}, \begin{bmatrix} 12.5 \\ 1.6 \\ 3.5 \\ 13.3 \end{bmatrix}\right), \text{if}\left(\phi = \frac{7}{8}\cdot in, \begin{bmatrix} 1 \\ 2 \\ \\ \end{bmatrix} \right.\right.\right.\right.$$

$$q_N := \text{if}\left(\left(f'_c \ge 3\cdot ksi\right)\cdot\left(f'_c \le 4\cdot ksi\right), \left(k_0 + k_1\cdot\left(\frac{f'_c}{ksi} - k_2\right)\right)\cdot kip, \text{if}\left(\left(f'_c > 4\cdot ksi\right), k_3\cdot kip, 0\cdot kip\right)\right)$$

$$q_N = 12.9\ kip$$

Strength reduction factor C_L for lightweight concrete

The allowable shear load for stud connectors may have to reduced when lightweight concrete is used. AISC Specification, Table I4.2, shows the strength reduction factors for use of lightweight concrete for concrete strengths less than or equal to 4 ksi and greater than or equal to 5 ksi, and for seven unit concrete weights from 90 pcf to 120 pcf in 5 pcf increments. This application interpolates Table I4.2 for any specified concrete strength and for any specified unit concrete weight between 90 and 120 pcf. If concrete weight is above 120 pcf, the concrete is assumed to be normal weight concrete made with ASTM C33 aggregates. If concrete weight is between 90 pcf and 120 pcf, the concrete is assumed to be lightweight concrete made with ASTM C330 aggregates.

Unit concrete weights in AISC Specification, Table I4.2:

$i := 0..6$ (one element i for each unit weight)

$Wt_i := (90 + 5 \cdot i) \cdot pcf$

$Wt^T = [90\ \ 95\ \ 100\ \ 105\ \ 110\ \ 115\ \ 120]\ pcf$

Factor X1, difference between the specified concrete strength and 4 ksi:

$$X1 := \frac{f'_c}{ksi} - 4$$

Factor X2, the strength reduction factor for all tabulated unit weights Wt, at the specified concrete strength f'c:

$$X2 := \text{if}\left(f'_c \le 4 \cdot ksi, \begin{bmatrix} 0.73 \\ 0.76 \\ 0.78 \\ 0.81 \\ 0.83 \\ 0.86 \\ 0.88 \end{bmatrix}, \text{if}\left(f'_c \ge 5 \cdot ksi, \begin{bmatrix} 0.82 \\ 0.85 \\ 0.87 \\ 0.91 \\ 0.93 \\ 0.96 \\ 0.99 \end{bmatrix}, \begin{bmatrix} 0.73 + X1 \cdot 0.09 \\ 0.76 + X1 \cdot 0.09 \\ 0.78 + X1 \cdot 0.09 \\ 0.81 + X1 \cdot 0.10 \\ 0.83 + X1 \cdot 0.10 \\ 0.86 + X1 \cdot 0.10 \\ 0.88 + X1 \cdot 0.11 \end{bmatrix} \right) \right)$$

$$Wt = \begin{bmatrix} 90 \\ 95 \\ 100 \\ 105 \\ 110 \\ 115 \\ 120 \end{bmatrix} pcf \qquad X2 = \begin{bmatrix} 0.73 \\ 0.76 \\ 0.78 \\ 0.81 \\ 0.83 \\ 0.86 \\ 0.88 \end{bmatrix}$$

Index number u for the tabulated unit weight Wt that is just less than the specified unit weight w_c:

$$index_0 := 0 \qquad u := index_0 \qquad u = 0$$

$$index_{0 \cdot i} := \text{if}\left(Wt_i \le w_c, i, index_0\right)$$

Strength reduction factor C_L at the specified unit weight wc:

$$C_L := X2_u + \frac{Wt_u - w_c}{5 \cdot pcf} \cdot \left(X2_{u+1} - X2_{u+1}\right) \qquad C_L = 0.73$$

Reduction factor C_T for formed steel deck with ribs transverse to beam span

Number of stud connectors per rib, limited to a maximum of 3, AISC Specification, Section I5:

$$N_r := \text{if}\left(N_r > 3, 3, N_r\right) \qquad N_r = 3$$

Length of stud connectors limited to a minimum of the rib height plus 1.5 inches and a maximum of the rib height h_r plus 3 inches, AISC Specification, Section I5:

$$H_s := \text{if}\left(H_s > h_r + 3 \cdot in, h_r + 3 \cdot in, \text{if}\left(H_s < h_r + 1.5 \cdot in, h_r + 1.5 \cdot in, H_s\right)\right)$$

$$H_s = 4.5\ in$$

Reduction factor C_T calculated using AISC Specification, Eq. (I5-1):

$$C_T := \text{if}\left(h_r = 0 \cdot in, 1, \text{if}\left(\frac{0.85}{\sqrt{N_r}} \cdot \frac{w_r}{h_r} \cdot \left(\frac{H_s}{h_r} - 1.0\right) \le 1.0, \frac{0.85}{\sqrt{N_r}} \cdot \frac{w_r}{h_r} \cdot \left(\frac{H_s}{h_r} - 1.0\right), 1.0\right)\right)$$

$$C_T = 0.859$$

Reduction factor C_P for formed steel deck with ribs parallel to beam span

Reduction factor C_P calculated using AISC Specification, Eq. (I5-2):

$$C_P := \text{if}\left(h_r = 0 \cdot in, 0, \text{if}\left(\left(0.6 \cdot \frac{w_r}{h_r} \cdot \left(\frac{H_s}{h_r} - 1.0\right) \le 1.0\right) \cdot \left(\frac{w_r}{h_r} < 1.5\right), 0.6 \cdot \frac{w_r}{h_r} \cdot \left(\frac{H_s}{h_r} - 1.0\right), 1.0\right)\right)$$

$$C_P = 1$$

Allowable shear load per stud for solid slabs with specified unit weight w_c:

$q := C_L \cdot q_N$ $\qquad$ $q = 9.417\ kip$

Allowable shear load per stud with formed steel deck transverse to beam span:

$q_T := C_L \cdot C_T \cdot q_N$ $\qquad$ $q_T = 8.087\ kip$

Allowable shear load per stud with formed steel deck parallel to beam span:

$q_P := C_L \cdot C_P \cdot q_N$ $\qquad$ $q_P = 9.417\ kip$

Summary

Input

Specified compressive strength of concrete: $\qquad$ $f'_c = 3.75\ ksi$

Unit weight of concrete (minimum weight of 90 pcf): $\qquad$ $w_c = 107\ pcf$

Stud diameter: $\qquad$ $\phi = 0.75\ in$

Nominal rib height: $h_r = 3$ ***in***

Length of stud connector after welding, (not to exceed h_r + 3" in computations): $H_s = 4.5$ ***in***

Number of shear connectors on beam in one rib, (not to exceed 3 in computations): $N_r = 3$

Average width of concrete rib or haunch: $w_r = 10.5$ ***in***

Computed Values

Capacity reduction factor for lightweight concrete (w_c between 90 and 120 pcf): $C_L = 0.73$

Capacity reduction factor for formed steel deck ribs transverse to beam span: $C_T = 0.859$

Capacity reduction factor for formed steel deck ribs parallel to beam span: $C_P = 1$

Allowable shear load per stud in a solid slab of normal weight concrete: $q_N = 12.9$ ***kip***

Allowable shear load per stud in a solid slab with specified unit weight of concrete: $q = 9.417$ ***kip***

Allowable shear load per stud with formed steel deck transverse to beam span: $q_T = 8.087\ \boldsymbol{kip}$

Allowable shear load per stud with formed steel deck parallel to beam span: $q_P = 9.417\ \boldsymbol{kip}$
