

# **Essential Equations for the Civil PE Exam Using the HP 33s**

**David V. Morse, PhD, PE**

**R. Wane Schneiter, PhD, PE, DEE**

**Norman R. Voigt, PE, PLS**

**Bruce A. Wolle, MSE, PE**

**Professional Publications, Inc.  
Belmont, CA**

**Equation 26: Distance From Neutral Axis to Bottom of Steel Beam**

$$\bar{y}_b = \frac{A_s \left( \frac{d}{2} \right) + A_{ctr} (d + Y2)}{A_s + A_{ctr}}$$

**Entered as**

$$B = (S \times D \div 2 + C \times (D + Y) ) \div ( S + C )$$

**Discipline** Structural

**Variables** (See How to Use This Book for more information.)

- $B = \bar{y}_b$  distance from neutral axis of composite beam to bottom of steel beam under full composite action in
- $S = A_s$  area of steel beam in<sup>2</sup>
- $D = d$  depth of steel beam in
- $C = A_{ctr}$  area of transformed concrete in<sup>2</sup>
- $Y = Y2$  distance from top of steel beam to centroid of concrete compressive area in

Keys	Display	Description
EQN	B= ■	Selects Equation mode and starts new equation. <i>B</i> is distance from neutral axis to bottom of beam ( $\bar{y}_b$ ).
B		
(	B= ( S ■	<i>S</i> is area of steel beam ( $A_s$ ).
D	B= ( S × D ■	<i>D</i> is depth of steel beam ( <i>d</i> ).
2	B= ( S × D ÷ 2 _	Cursor changes for entering digits.
C	B= ( S × D ÷ 2 + C ■	<i>C</i> is area of concrete ( $A_{ctr}$ ).
(	( S × D ÷ 2 + C × ( D + Y ■	<i>Y</i> is distance from top of beam to centroid of concrete ( <i>Y2</i> ). Equation is now longer than the hp 33s display. For instructions on scrolling left and right, see How to Use This Book.
D		
Y		
)	2 + C × ( D + Y ) ÷ ( S ■	
S		

$\times (D+Y) \div (S+C) \blacksquare$

$B = (S \times D \div 2 + C \times (D +$  Ends equation.

$CK=D7EA$  Hold down SHOW to display  
 $LN=23$  checksum and length of equation.  
 If numbers displayed match these,  
 equation is correctly entered.

### Equations 27-28: Ordinates of Reinforced Concrete Interaction Diagram

$$x = \frac{\phi M_n}{A_g h}$$

$$y = \frac{\phi P_n}{A_g}$$

**Entered as**

$$X = P \times M \div A \div H$$

$$Y = P \times N \div A$$

**Discipline** Structural

**Variables** (See How to Use This Book for more information.)

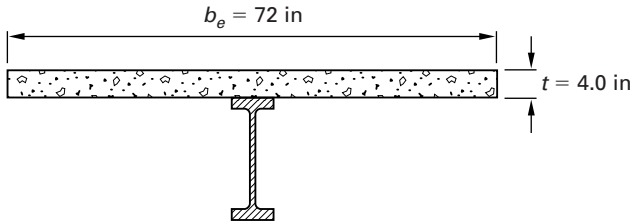
- $X = x$  value on  $x$ -axis ksi
- $P = \phi$  strength reduction factor -
- $M = M_n$  nominal moment in-kips
- $A = A_g$  gross area  $\text{in}^2$
- $H = h$  effective height in
- $Y = y$  value on  $y$ -axis ksi
- $N = P_n$  nominal axial load kips

**Notes** These equations are used to find quickly the  $x$ - and  $y$ -values to use with a reinforced concrete interaction diagram. If the two equations are used one right after the other, the values for  $\phi$  and  $A_g$  do not have to be keyed in again the second time.

Keys	Display	Description
	$X = \blacksquare$	Selects Equation mode and starts new equation. $X$ is value on $x$ -axis.

**PROBLEM 8**

The W18 × 40 composite steel beam shown supporting a 4 in concrete slab spans 30 ft. The modular ratio is 8.



If the concrete slab is transformed to steel, what is the distance from the bottom of the beam to the centroid of the transformed section?

- (A) 14 in
- (B) 16 in
- (C) 17 in
- (D) 19 in

**SOLUTION 8**

Find the section properties of a W18 × 40 beam in Part 1 of the AISC ASD manual.

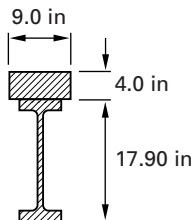
$$b_f = 6.0 \text{ in}$$

$$A = 11.8 \text{ in}^2$$

$$d = 17.90 \text{ in}$$

To find the centroid of the transformed area, determine the equivalent width of the transformed concrete.

$$\begin{aligned} b_{\text{transformed}} &= \left(\frac{1}{n}\right) b_e = \left(\frac{1}{8}\right) (72 \text{ in}) \\ &= 9.0 \text{ in} \end{aligned}$$



Use the equation for the distance from the neutral axis to the bottom of a steel beam (Equation 26, p. 38). The area of the steel beam is calculated here within the solving process; it could also be calculated before entering Equation mode.  $Y$  equals half the thickness of the transformed concrete.

Keys	Display	Description
EQN	$B = (S \times D \div 2 + C \times (D +$	Enters Equation mode. Scroll through list to bring needed equation to bottom line of display.
ENTER	S? 0.0000	Starts to solve for $B$ . Prompts for $S$ and displays current value.
1 1 .	D? 0.0000	Enters 11.8 for $S$ . Prompts for $D$ and displays current value.
8 R/S		
1 7 .	C? 0.0000	Enters 17.9 for $D$ . Prompts for $C$ and displays current value.
9 R/S		
9 ENTER	Y? 0.0000	Enters $9 \times 4$ for $C$ . Prompts for $Y$ and displays current value.
4 X R/S		
2 R/S	B = 17.1969	Enters 2 for $Y$ and solves for $B$ .

The answer is (C).

**PROBLEM 9**

A 20 in by 24 in short concrete column carries an axial factored load of 750 kips and a factored moment of 600 ft-kips. Bars are located on the short faces of the columns and  $\gamma$  is 0.75. The concrete has a compressive strength of 4000 lbf/in<sup>2</sup> and the reinforcement has a yield stress of 60,000 lbf/in<sup>2</sup>. The required area of steel is most nearly

- (A) 12 in<sup>2</sup>
- (B) 14 in<sup>2</sup>
- (C) 19 in<sup>2</sup>
- (D) 36 in<sup>2</sup>