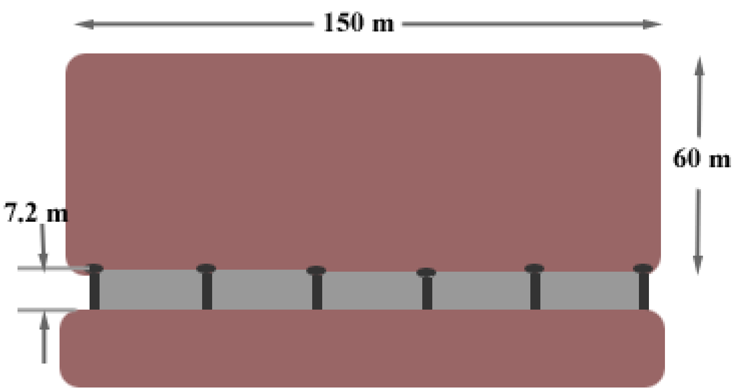
49.

<u>Problem 13.52P (HRW)</u>

A tunnel 150 m *long,* 7.2 m *high, and* 5.8 m *wide* (*with a flat roof*) *is to be constructed 60 m beneath the ground. The tunnel roof is to be supported entirely by square steel columns, each with a cross-sectional area of* 960 cm^2. *The density of the ground material is* 2.8 gm cm^{-3}. (a) *What is the total weight that the column must support? How many columns are needed to keep the compressive stress on each column at one-half its ultimate strength?*



Solution:

Dimensions of the tunnel are length, $l = 150\ \text{m}$, width, $w = 5.8\ \text{m}$, and height, $h = 7.2\ \text{m}$.

Depth of the tunnel from the ground, $H = 60\ \text{m}$.

Volume of the ground material above the tunnel,

$V = H \times l \times w = 60 \times 150 \times 5.8\ \text{m}^3 = 5.22 \times 10^4\ \text{m}^3$.

Density of the ground material, $\rho = 2.8 \times 10^3\ \text{kg m}^{-3}$.

Weight of the ground material on the tunnel,

$$W = V\rho g = 5.22 \times 10^4 \times 2.8 \times 10^3 \times 9.8\ \text{N}$$
$$= 1.43 \times 10^9\ \text{N}.$$

It is given that the planned maximum compression stress on each column is $\frac{1}{2}$ of the ultimate strength of concrete, that is $20 \times 10^6\ \text{N m}^{-2}$. Cross-sectional area of each column is $A = 9.6 \times 10^{-2}\ \text{m}^2$. Therefore, maximum force that each column can support will be $20 \times 10^6 \times 9.6 \times 10^{-2}$ N= 1.9×10^6 N.

Therefore, number of concrete columns, *N*, required in the tunnel is given by the expression

$$N = \frac{\text{weight of the ground material to be supported}}{\text{maximum force that each column can support}}$$

$$= \frac{1.43 \times 10^9}{1.9 \times 10^6} = 750.$$