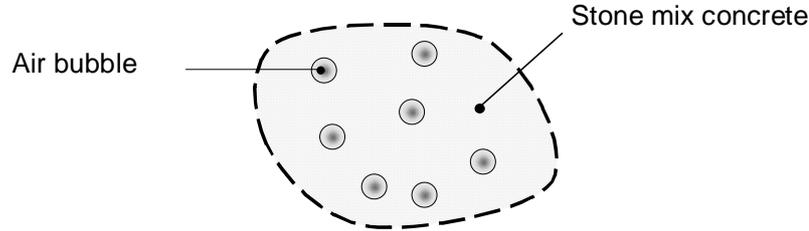


PROBLEM 3.37

KNOWN: Volume fraction of air in stone mix concrete, forming a lightweight aggregate concrete.

FIND: Values of the lightweight aggregate's thermal conductivity, density and specific heat.

SCHEMATIC:



ASSUMPTIONS: (1) Constant properties.

PROPERTIES: Table A.3 ($T = 300 \text{ K}$): Stone mix concrete; $k_s = 1.4 \text{ W/m}\cdot\text{K}$, $\rho_s = 2300 \text{ kg/m}^3$, $c_{p,s} = 880 \text{ J/kg}\cdot\text{K}$. Table A.4 ($T = 300 \text{ K}$): Air; $k_f = 0.0263 \text{ W/m}\cdot\text{K}$, $\rho_f = 1.1614 \text{ kg/m}^3$, $c_{p,f} = 1007 \text{ J/kg}\cdot\text{K}$.

ANALYSIS: Maxwell's expression for the effective thermal conductivity may be used. Hence,

$$\begin{aligned}
 k_{\text{eff},a} &= \left[\frac{k_f + 2k_s - 2\varepsilon(k_s - k_f)}{k_f + 2k_s + \varepsilon(k_s - k_f)} \right] k_s \\
 &= \left[\frac{0.0263 \text{ W/m}\cdot\text{K} + 2 \times 1.4 \text{ W/m}\cdot\text{K} - 2 \times 0.35 \times (1.4 \text{ W/m}\cdot\text{K} - 0.0263 \text{ W/m}\cdot\text{K})}{0.0263 \text{ W/m}\cdot\text{K} + 2 \times 1.4 \text{ W/m}\cdot\text{K} + 0.35 \times (1.4 \text{ W/m}\cdot\text{K} - 0.0263 \text{ W/m}\cdot\text{K})} \right] \times 1.4 \text{ W/m}\cdot\text{K} \\
 &= 0.789 \text{ W/m}\cdot\text{K} <
 \end{aligned}$$

Considering the control volume shown in the schematic to be of unit volume, we note that by conservation of mass, $\rho_a = \rho_s(1 - \varepsilon) + \rho_f\varepsilon = 2300 \text{ kg/m}^3 \times (1 - 0.35) + 1.1614 \text{ kg/m}^3 \times 0.35 = 1495 \text{ kg/m}^3$. <

Similarly, by conservation of energy for the unit volume, $\rho_a c_{p,a} = 1495 \text{ kg/m}^3 \times c_{p,a} = \rho_s c_{p,s}(1 - \varepsilon) + \rho_f c_{p,f} \varepsilon = 2300 \text{ kg/m}^3 \times 880 \text{ J/kg}\cdot\text{K} \times (1 - 0.35) + 1.1614 \text{ kg/m}^3 \times 1007 \text{ J/kg}\cdot\text{K} \times 0.35 = 1.32 \times 10^6 \text{ J/K}$.
Therefore, $c_{p,a} = 1.32 \times 10^6 \text{ J/K} / 1495 \text{ kg/m}^3 = 880 \text{ J/kg}\cdot\text{K}$ <

COMMENT: The thermal conductivity and density are reduced significantly relative to the stone mix concrete values.