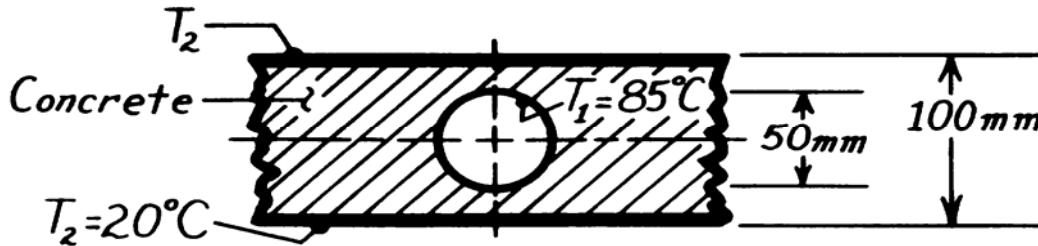


PROBLEM 4.14

KNOWN: Tube embedded in the center plane of a concrete slab.

FIND: The shape factor and heat transfer rate per unit length using the appropriate tabulated relation,

SCHEMATIC:



ASSUMPTIONS: (1) Two-dimensional conduction, (2) Steady-state conditions, (3) Constant properties, (4) Concrete slab infinitely long in horizontal plane, $L \gg z$.

PROPERTIES: Table A-3, Concrete, stone mix (300K): $k = 1.4 \text{ W/m}\cdot\text{K}$.

ANALYSIS: If we relax the restriction that $z \gg D/2$, the embedded tube-slab system corresponds to the fifth case of Table 4.1. Hence,

$$S = \frac{2\pi L}{\ln(8z/\pi D)}$$

where L is the length of the system normal to the page, z is the half-thickness of the slab and D is the diameter of the tube. Substituting numerical values, find

$$S = 2\pi L / \ln(8 \times 50\text{mm} / \pi 50\text{mm}) = 6.72L.$$

Hence, the heat rate per unit length is

$$q' = \frac{q}{L} = \frac{S}{L} k (T_1 - T_2) = 6.72 \times 1.4 \frac{\text{W}}{\text{m}\cdot\text{K}} (85 - 20)^\circ \text{C} = 612 \text{ W}.$$