# TYPE 714: ASHRAE METHOD FOR CALCULATING SLAB HEAT TRANSFER

## General Description

In 2001 ASHRAE Fundamentals Chapter 31, the American Society of Heating and Refrigeration Engineers proposes a simplified method for calculating the energy transfer through a rectangular slab on grade with various insulation schemes (back insulation, side insulation, no insulation, etc.). The same chapter extends the simplified method to calculating energy transfer through basements. This Type should be used for slabs while Type715 is available for calculating energy transfer through basements.

## Nomenclature

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|---|---|---|
| $\dot{q}_{slab}$ | [kJ/hr] | The rate at which energy is transferred through the slab (positive is defined as energy exiting the slab) |
| $\dot{q}_{mean}$ | [kJ/hr] | The average annual rate at which energy is transferred through the slab |
| $\dot{q}_{amp}$ | [kJ/hr] | The amplitude of the sinusoidal rate at which energy is transferred through the slab. |
| $\omega$ | [radians/hr] | The annual angular frequency ( $7.17 \times 10^{-4}$ rad/hr ) |
| $time$ | [hr] | The hour of the year |
| $\phi$ | [hr] | The phase lag between the hottest hour of the year and the hour in which the maximum energy transfer through the slab is experienced. |
| $U_o, G, H, D$ | [various] | Model fitting parameters. |
| $k_{soil}$ | [kJ/hr.m.K] | The thermal conductivity of the soil. |
| $A_{slab}$ | [$m^2$] | The top area of the slab |
| $P_{slab}$ | [m] | The perimeter of the slab |
| $R_{equivalent}$ | [hr.$m^2$.K/kJ] | The equivalent thermal resistance of the slab |
| $\alpha_{soil}$ | [$m^2$/hr] | The thermal diffusivity of the slab |
| $R_{insul}$ | [hr.$m^2$.K/kJ] | The thermal resistance of the insulation material |
| $R_{slab}$ | [hr.$m^2$.K/kJ] | The thermal resistance of the slab material |
| $L_{insul}$ | [m] | The length of the slab |
| $\rho_{soil}$ | [kg/$m^3$] | The density of the soil |
| $Cp_{soil}$ | [kJ/kg.K] | The specific heat of the soil |
| $U_{eff,mean}$ | [kJ/hr.$m^2$.K] | The mean heat loss coefficient for the slab and insulation |
| $U_{eff,amp}$ | [kJ/hr.$m^2$.K] | The difference between the maximum heat loss coefficient for the slab and insulation and the average heat loss coefficient for the slab and insulation |
| $T_{mean,indoor}$ | [ºC] | The average indoor temperature (on the top surface of the slab) |
| $T_{mean,ambient}$ | [ºC] | The average outdoor temperature |
| $T_{amp}$ | [ºC] | The difference between the maximum outdoor temperature and the average outdoor temperature. |

## Detailed Description

The 2001 ASHRAE Fundamentals Handbook, Chapter 31 presents a simplified method for estimating energy transfer through slabs and basements. The configuration modeled by this Type is that of a rectangular slab that may or may not be insulated on its back side and that may or may not be insulated around its perimeter. A schematic drawing of such a slab is shown in Figure 1. The Figure 1 slab is shown as having back insulation but no side insulation.

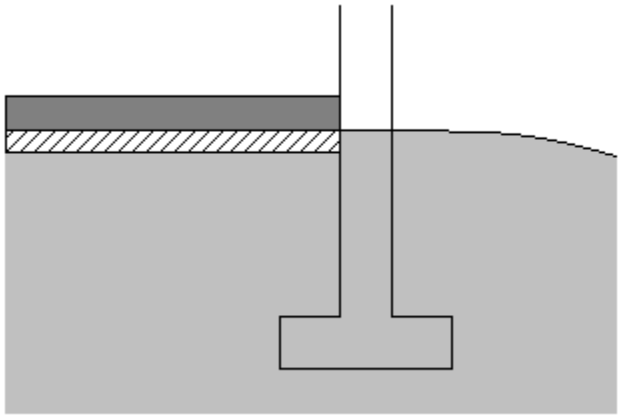


*Figure 1: Slab Configuration (Reproduced from 2001 ASHRAE Fundamentals)*

The energy transferred through the slab at any point in time is given by Equation 714.1 (ASHRAE equation 5).

$$\dot{q}_{slab} = \dot{q}_{mean} + \dot{q}_{amp} \sin(\omega\, time + \phi) \qquad \text{(Eq. 714.1)}$$

In which ω is the annual angular frequency (expressed in radians / hour) and ϕ is the phase lag (in hours) between the maximum annual temperature and the maximum annual energy transfer through the slab. In essence, equation 714.1 indicates that the energy transfer through the slab follows a sinusoidal function about the mean energy transfer rate and with a certain amplitude.

The mean energy transfer and the amplitude of the energy transfer are calculated as follows. First, the soil conductivity is normalized to form four parameters $U_o$, G, H and D. The first, $U_o$, requires only the soil conductivity, the area and the perimeter of the slab.

$$U_o = \frac{k_{soil}}{\left(\frac{A_{slab}}{P_{slab}}\right)} \qquad \text{(Eq. 714.2)}$$

In the second, G, an equivalent thermal resistance of the insulation and the annual angular frequency are introduced. The equivalent resistance is calculated using equation 714.6 (ASHRAE equation 14) while the annual angular frequency is given by equation 714.7. Equation 714.3 (ASHRAE equation 12) also requires the thermal diffusivity of the soil, a value that is calculated from the models parameters using equation 714.8.

$$G = k_{soil}\ R_{equivalent} \sqrt{\frac{\omega}{\alpha_{soil}}} \qquad \text{(Eq. 714.3)}$$

The H parameter is given by equation 714.4 (ASHRAE equation 15).

$$H = \frac{\left(\frac{A_{slab}}{P_{slab}}\right)}{k_{soil}\ R_{equivalent}} \qquad \text{(Eq. 714.4)}$$

The D parameter is given by equation 714.5 (ASHRAE equation 16) as a function of H.

$$D = \ln\left[(1+H)\left(1+\frac{1}{H}\right)^{H}\right] \qquad \text{(Eq. 714.5)}$$

The equivalent resistance of the slab and insulation is given by equation 714.6 (ASHRAE equation 14).

$$R_{equivalent} = \frac{R_{slab}}{\left[1-\left(\frac{\frac{L_{insul}}{A_{slab}}}{P_{slab}}\ \frac{R_{insul}}{R_{slab}+R_{insul}}\right)\right]} \qquad \text{(Eq. 714.6)}$$

Since the period of the sinusoid that is used to describe energy transfer through the slab is one year, the frequency of that sinusoid, expressed in radians per hour is given by equation 714.7.

$$\omega = \frac{2\,\pi}{8760} \qquad \text{(Eq. 714.7)}$$

The thermal diffusivity of the soil is given by 714.8.

$$\alpha_{soil} = \frac{k_{soil}}{\rho_{soil}\ Cp_{soil}} \qquad \text{(Eq. 714.8)}$$

The Uo, G, D, and H parameters are next combined to find the effective mean loss coefficient as shown in equation 714.9 (ASHRAE equation 17) and the amplitude of the loss coefficient as given by equation 714.10 (ASHRAE equation 18).

$$U_{eff,mean} = 0.4\,U_o\ D \qquad \text{(Eq. 714.9)}$$

$$U_{eff,amp} = 0.25\,U_o\ D^{0.16}\ G^{-0.6} \qquad \text{(Eq. 714.10)}$$

The coefficients 0.4 and 0.25 are taken from ASHRAE Table 2 in chapter 31. In fact ASHRAE gives a number of different coefficient values for situations in which the slab is only partially insulated. Type714, however, assumes that the entire back of the slab is insulated.

With the loss coefficients in hand, the energy transferred through the slab can next be calculated using equations 714.11 and 714.12 (ASHRAE equations 19 and 20).

$$\dot{q}_{eff,mean} = U_{eff,mean}\ A_{slab}\ \left(T_{mean,indoor} - T_{mean,ambient}\right) \quad \text{(Eq. 714.11)}$$

$$\dot{q}_{eff,amp} = U_{eff,amp}\ A_{slab}\ T_{amp} \quad \text{(Eq. 714.12)}$$

Where $T_{amp}$ is the amplitude of the annual ambient temperature.

**References**

[1] 2001 ASHRAE Handbook of Fundamentals, Chapter 31