

# SLAB

## Heat losses to the ground from buildings

Version 2.0

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Prof. Carl-Eric Hagentoft

Dept. of Building Physics, Chalmers University of Technology, Gothenburg, Sweden

Dr. Thomas Blomberg

Building Technology Group, Massachusetts Inst. of Technology, Cambridge, USA  
Dept. of Building Physics, Lund University, P.O.Box 118, SE-221 00 Lund, Sweden

# 1 Introduction

## 1.1 Overview

The PC-program **SLAB** calculates the heat loss to the ground from an evenly insulated rectangular slab on the ground. Both the heat loss variation during the year, including the peak effect, and the accumulated heat loss during the heating season are calculated. The results are based on heat conduction in a semi-infinite ground with homogeneous soil. The effect of moisture movements or changes in moisture content are not considered.

## 2 Mathematical description

Figure 1 shows a building with the considered type of foundation. It is thermally insulated towards the ground.

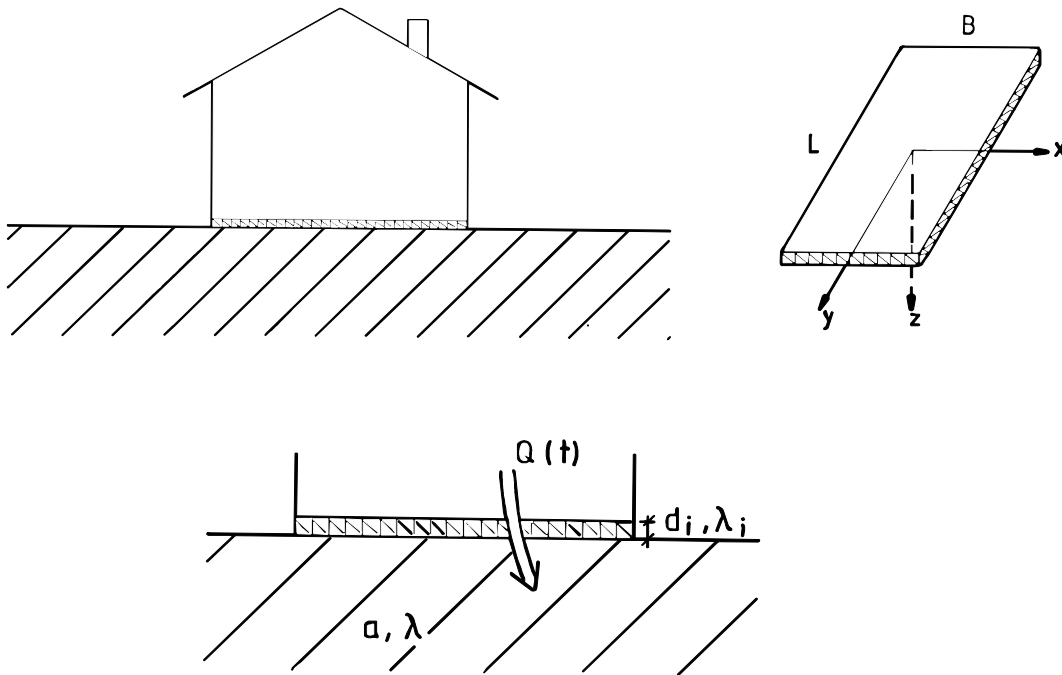


Figure 1: Buildings with foundation of the type slab on the ground.

### 2.1 Governing equation

The ground is assumed to be homogeneous with constant thermal conductivity  $\lambda$  (W/mK) and volumetric heat capacity  $C$  ( $= \rho c$ ) (J/m<sup>3</sup>K). The governing equation for conductive heat flow in the ground is:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = \frac{\rho c}{\lambda} \frac{\partial T}{\partial t} \quad (1)$$

The solution of the equation is obtained from a combination of numerical results (FDM) and analytical solutions, see (Hagentoft, 1988).

## 2.2 Heat loss

The heat loss,  $Q(t)$  (W), through the floor surface,  $S$ , becomes:

$$Q(t) = \iint_S -\lambda \frac{\partial T}{\partial n} dS \quad (2)$$

## 2.3 Boundary condition at the interior

The temperature in the building is constant  $T_i$ . The thickness of the thermal insulation at the floor is  $d_i$  (m), and the thermal conductivity is  $\lambda_i$  (W/mK). The boundary condition becomes:

$$\frac{T_i - T}{d_i/\lambda_i} = -\lambda \frac{\partial T}{\partial n} \quad (3)$$

Here,  $d_i/\lambda_i$  (m<sup>2</sup>K/W) should be interpreted as the total thermal resistance between the interior and the soil.

## 2.4 Boundary condition at the exterior

The outdoor temperature may vary strongly during the day, and from day to day. However, variations with a short time period or duration can be neglected.

The following approximation of the outdoor temperature is used:

$$T_{out}(t) = T_0 + T_1 \cdot \sin(2\pi(t/t_p - \phi_1)) \quad (4)$$

Here,  $T_0$  is the annual mean temperature, and  $T_1$  is the seasonal amplitude of the temperature variation with the time period,  $t_p$ , of one year. The phase  $\phi_1$  is chosen in order to achieve the maximum outdoor temperature at the right time of the year.

The sinusoidal temperature, (4), represents a mean temperature during the winter months. In order to calculate the peak effect we need to represent the outdoor temperature in greater detail, in particular during the coldest period. It should normally be sufficient to use a single suitably chosen pulse, which the duration time  $t_2$ . The magnitude of the pulse is  $T_2$ . The value of  $T_2$  is negative for a cold spell. The maximum heat loss is obtained at the end of the pulse.

## 2.5 Heat loss during the heating season

The heat loss to the ground is denoted by  $Q(t)$  (W). We get a steady-state (time-independent) component  $Q_s$  and a periodic one  $Q_p(t)$ :

$$Q(t) = Q_s + Q_p(t) \quad (5)$$

The accumulated heat loss over the heating season, starting at the time  $t_a$  of the year and ending at  $t_b$ , becomes:

$$E_y = \int_{t_a}^{t_b} Q(t) dt \quad (6)$$

Let  $Q_t(t)$  denote the extra heat loss due to a cold spell. The peak heat loss due to a superimposed cold spell becomes:

$$Q(t) = Q_s + Q_p(t) + Q_t(t_2) \quad (7)$$

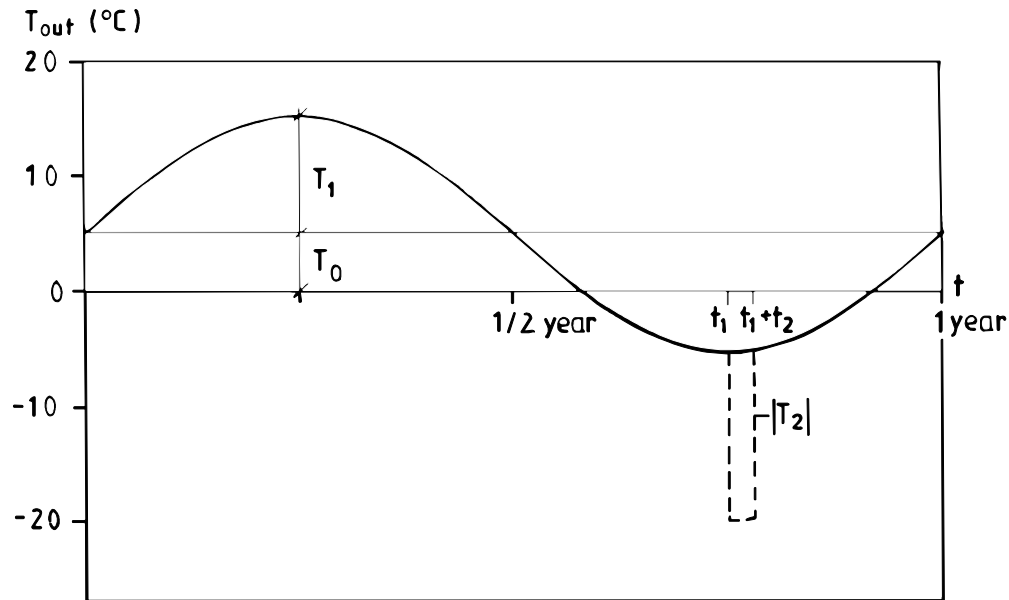


Figure 2: Representation of the outdoor temperature for the calculation of the energy demand (continuous curve) and the peak effect (continuous + dashed curve).

### 3 Working with SLAB

#### 3.1 Input data

The following input data are required by the PC-programs:

$L$	Length of building (m)
$B$	Width of building (m)
$T_i$	Indoor temperature ( $°C$ )
$T_0$	Annual mean outdoor temperature ( $°C$ )
$T_1$	Amplitude of the periodic outdoor temperature ( $°C$ )
$\lambda_i$	Thermal conductivity of the floor insulation (W/mK)
$d_i$	Insulation thickness of the floor (m)
$\lambda$	Thermal conductivity of the ground (W/mK)
$C$	Volumetric heat capacity, $\rho c$ , of the ground ( $J/m^3K$ )
$t_a$	Start time for the heating season, day of the year, (days)
$t_b$	End time for the heating season, day of the year, (days)
$T_2$	Increase of outdoor temperature due to temperature pulse ( $°C$ )
$t_2$	Duration time for the pulse (days)

The Input Data Window is shown in Figure 3.

Figure 3: Menu for input of data.

There are the following restrictions on the input variables:

$$L, B, d_i, \lambda_i, \lambda, C, t_2 > 0 \quad (8)$$

$$B \leq L \quad (9)$$

$$\frac{d_i \lambda / \lambda_i}{B} \geq 0.05 \quad (10)$$

As an alternative, English units (Btu, ft, h, °F) can be used both for the input data and the output. Alternation between SI-units and English units can be made in the Options menu.

The input data are tested so that they fall within acceptable limits.

### 3.2 Output data

The following output are produced:

$E_y$	Accumulated heat loss over the heating season (J, kWh).
$Q(t) _{max}$	Peak effect during the winter (W).
$Q_s$	Annual mean heat loss (W).
$Q_p _{max}$	Amplitude of the periodic heat loss (W).
$t_{lag}$	Time lag, (days), for the periodic heat loss.
$\phi_p$	The phase delay, (-), for the periodic heat loss.

The output data window is shown in Figure 4.

With these output data the heat loss (except for the pulse) becomes:

$$Q(t) = Q_s + Q_p|_{max} \cdot \sin(2\pi(t_{days}/365 - \phi - \phi_p)) \quad (11)$$

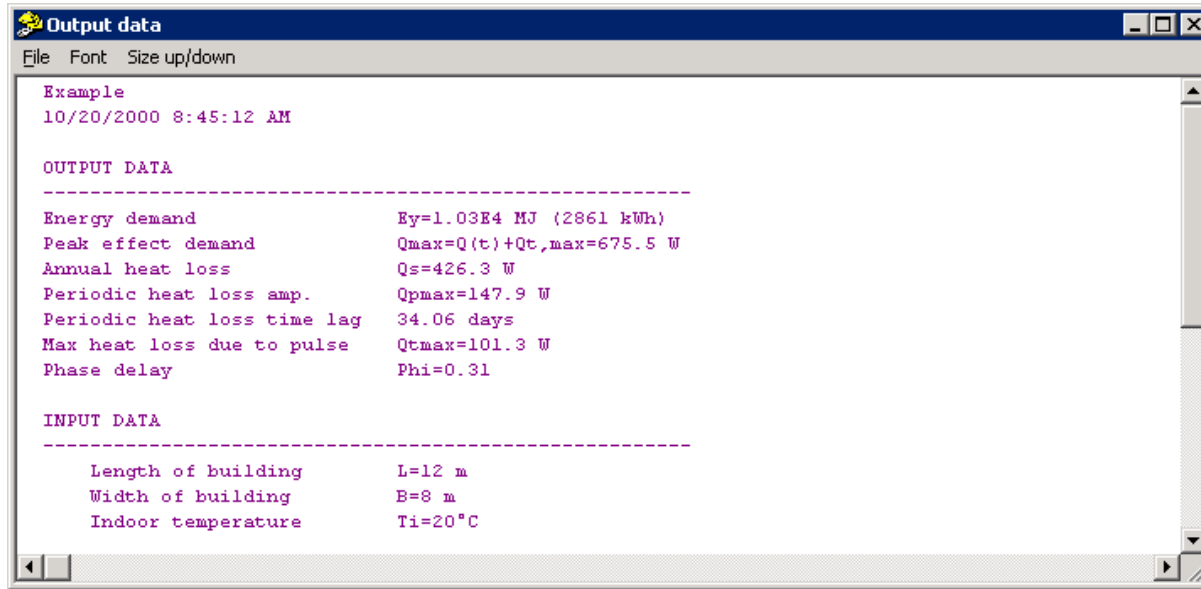


Figure 4: Menu for output of data.

The graphical window is shown in Figure 5.

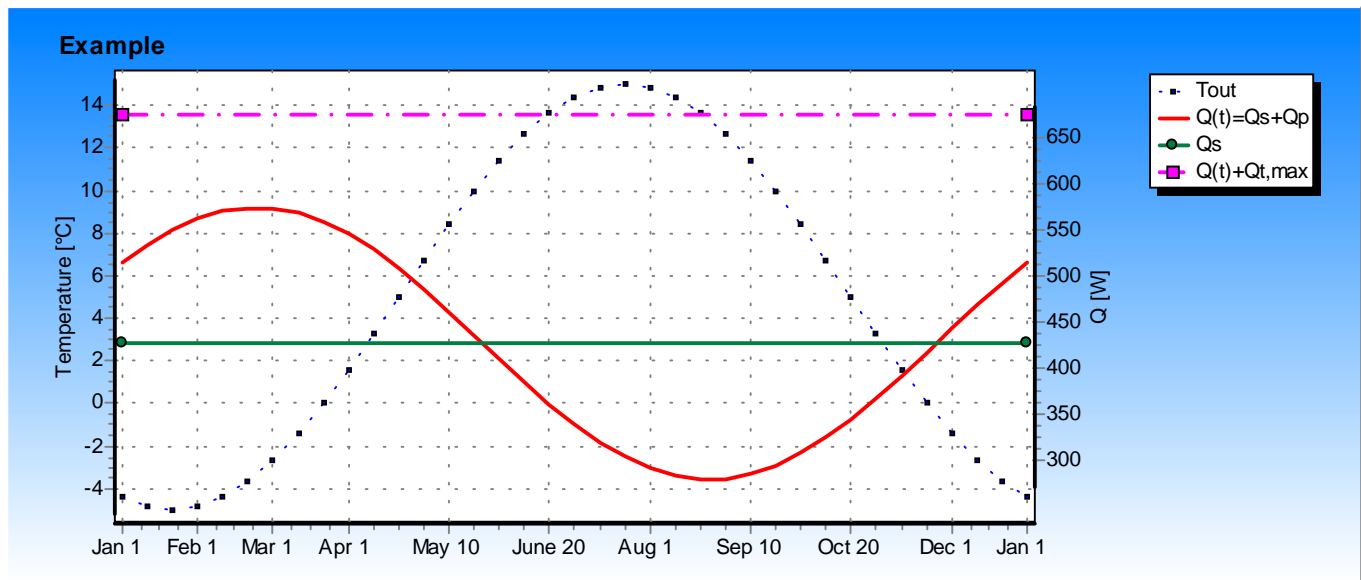


Figure 5: Menu showing a chart of the heat loss to the ground.

The chart shown in the Graph Window has several options, which is shown in Figure 6.

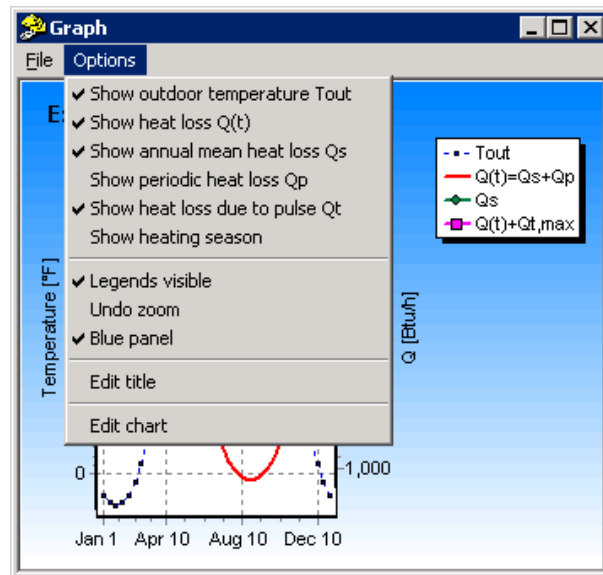


Figure 6: Sub-menu in the Graph window showing different options.

## References

1. Heat loss to the ground from a building. Slab on the ground and cellar. Thesis, LTH/TVBH-1004, 1988. Dept. of Building Physics, Lund University.

## Appendix A. Changing the chart properties

The properties of a chart may be changed by the chart editor (Options/Edit chart), see Figure A1.

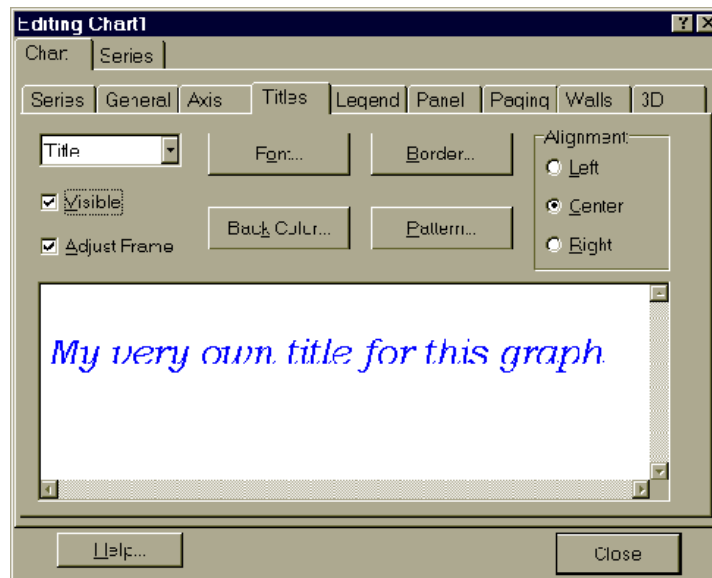


Figure A1: Chart settings may be changed in menu item Options/Edit chart.

There are two principal sections to the Chart editor, Chart parameters and the Series parameters, which are separated as two tabs of the Chart Editor. To get help on any topic in the Chart Editor, select the help button (question mark) at the top right hand side of the Editor window and drag it onto the Topic in question. Some of the chart display parameters is described below:

### Chart pages

**Series** - Change of a series type to line, bar, area, point, etc

**General** - Chart rectangle dimensions, margins, zoom and scroll, print preview and export

**Axis** - All axes definitions. Some parameters depend upon the series associated with the axis.

**Titles** - Title and Footer

**Legend** - Legend display. Formatted displays work in conjunction with the chart serie

**Panel** - Chart Panel display properties. Colors, bevels, back images, color gradient and border.

**Paging** - Definition of number of points per chart page

**Walls** - Left, bottom and back wall size and color definitions

**3D** - 3D perspective options.

### Series pages

**Format** - Contains Series type specific parameters

**Point** - Visible points, margins

**General** - Series value format, axis association

**Marks** - Series mark format, text, frame and back color and positioning