BASECALC™: NEW SOFTWARE FOR MODELLING BASEMENT AND SLAB-ON-GRADE HEAT LOSSES

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ABSTRACT

New software (BASECALCTM) has been created for modelling heat losses from residential basements and stabs-on-grade. A menu driven interface allows the user to quickly and efficiently describe how the basement or stab-on-grade is constructed, where insulation is placed, what type of insulation is used, and to select ground properties and weather. BASECALCTMthen performs a series of detailed finite-element calculations before presenting succinct, easy-to-read results to the user.

OBJECTIVES OF THE SOFTWARE

BASECALC™ was created to allow researchers, code writers and enforcers, insulation and building-component manufacturers, and builders to analyze the energy impact of insulation placements and products.

BASECALC™ can also be used by building-simulation software developers to create more accurate basement algorithms for their programs and by building-simulation software users to calibrate basement heat-loss predictions from building-simulation programs.

INTRODUCTION

Basements and slabs-on-grade account for 10% to 40% of the energy used to heat Canadian houses. Consequently, an accurate and easy-to-use method to model basement and slab-on-grade heat losses is required for determining appropriate insulation strategies and for establishing building- and energy-code requirements.

A new numerical technique to model basement and slab-on-grade heat losses was developed, its genesis the National Research Council of Canada's Mitalas method (Mitalas 1982, 1987). This technique, unlike its progenitor, models both above-grade and below-grade heat losses. The BASECALC™ software was created to allow easy and efficient application of this new basement heat-loss technique.

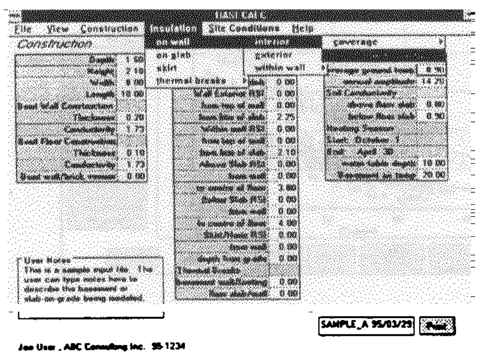
BASECALC™ is composed of a user-friendly interface and a calculation core. The interface allows the user to describe a basement's thermal and physical characteristics and to review calculation results, without a knowledge of the calculation core. The calculation core performs a series of finite-element calculations and processes the results with weather data to predict energy and heat losses, but this is all transparent to the user.

The design of the BASECALC™ interface and the operation of its calculation core are reviewed in the following sections. A sample analysis performed with BASECALC™ is also presented.

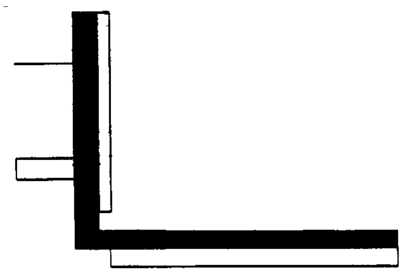
INTERFACE DESIGN

The BASECALC™ interface is written in Visual Basic for Windows.

The user enters data through a series of pull-down menus. The complete set of input data is displayed on a single screen to allow quick verification. Advanced users may bypass the pull-down menus by typing data directly into the display grids.

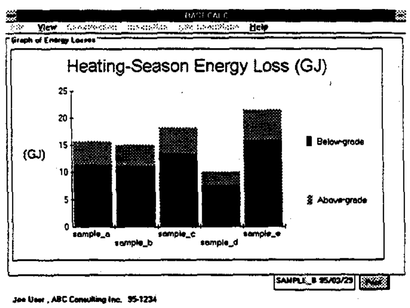


The user can quickly confirm their input with a view screen which displays a basement cross-section illustrating where insulation has been placed.

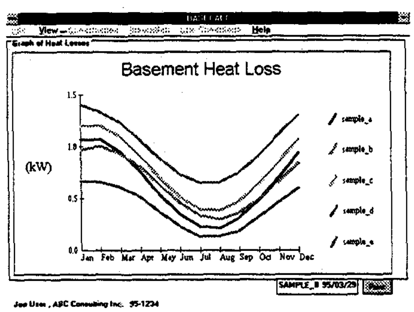


Once the data input is complete, the user saves the data to a file and performs a run. Single files or batches of files can be run, requiring minutes or weeks of CPU time.

BASECALC™ allows the user to view results numerically, in equation form, or to compare the results of several runs graphically. The graphical results are given in terms of above- and below-grade energy losses,



and in terms of heat loss as a function of time.



The BASECALC™ interface is bilingual (French/English) and easily adaptable to other languages as all text appearing on the screen is stored in ASCII files.

Other features include on-line help, a batch processor for performing multiple runs, and libraries of common insulation and construction materials.

THE CALCULATION CORE

When the user instructs BASECALC™ to perform a heat-loss analysis, the interface passes control to the calculation core. The user's input is processed and then Visual Basic "shells out" to a FORTRAN two-dimensional finite-element calculator. Once the finite-element calculations are complete—this takes 30 minutes on a 486 66MHz 16MB computer-—control is passed back to Visual Basic where the finite-element output is processed with weather data to predict energy and heat losses. The steps performed by the calculation core are briefly described below. A more in-depth description of the heat-loss technique will be given in a future paper.

The first step is to set up the problem for the finite-element calculator. A mesh of triangular elements is created—a base mesh is expanded and/or compressed horizontally and vertically—to fit the user's geometrical input (wall height, depth of slab, width of slab, etc.). BASECALC™ has one base mesh for slabs-on-grade and another for basements. The user's input defining insulation placement and resistance and soil type is used to set the thermal conductivities in the finite-element calculator.

The second step is to perform the two-dimensional finite-element calculations. Three separate finite-element calculations are performed, each with a different set of boundary conditions. The first run analyzes the above-grade heat loss, the second analyzes the annually-averaged below-grade heat loss, and the third analyzes the time-dependent below-grade heat loss. These finite-element calculations result in two-dimensional heat-loss factors; they do not account for three dimensional effects around the corners of the foundation.

The third step is to correct for the three-dimensional heat flow around the corners. Rather than perform three-dimensional finite-element calculations (this would take many hours of CPU time), BASECALC™ applies a simple technique called the *corner correction method* (Beausoleil-Morrison et al 1995) to estimate the three-dimensional effects around the corners.

The corner-correction method is essentially a series of correlation equations which relate the three-dimensional effects around corners to the foundation's and site's thermal and geometrical characteristics (insulation placement, insulation thermal resistance, soil conductivity, depth, water-table depth, and width). BASECALC™ uses these correlation equations to determine scaler multipliers to *correct* the two-dimensional finite-element calculations for three-dimensional effects. This results in a set of three-dimensional heat-loss factors.

The fourth step is to process the three-dimensional heat-loss factors with weather data to predict the energy and heat losses. BASECALC™ uses the monthly-averaged air temperatures to calculate the above-grade heat loss and the annually-averaged ground-surface temperature and the annual amplitude of the ground-surface temperature to calculate the below-grade heat loss.

SAMPLE ANALYSIS

To demonstrate how BASECALC™ can be used, four alternate insulation/construction configurations were analyzed in three different cities. Typical geometrical and thermal characteristics were used:

- depth of floor slab = 1.25m
- height of basement walls = 2.0m
- basement width = 8m
- basement length = 10m
- wall thickness = 0.200m
- slab thickness = 0.100m
- concrete conductivity = 1.73 W/mK
- insulation resistance = RSI 3
- conductivity of soil above slab = 0.8 W/mK
- conductivity of soil below slab = 0.9 W/mK
- water-table depth below grade = 10m
- basement air temperature = 20°C

The four alternate insulation configurations are:

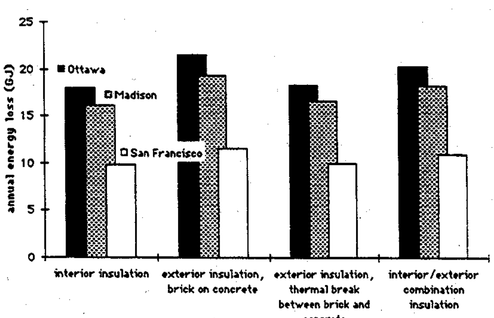
i) insulation fully covering inner wall surface; brick veneer of first storey resting on concrete basement wall

ii) insulation fully covering outer wall surface; brick veneer of first storey resting on concrete basement wall

iii) insulation fully covering outer wall surface; thermal break between brick veneer of first storey and concrete basement wall

iv) insulation on outer wall from grade to bottom of wall; insulation on inner wall from top of wall to 0.6m below grade; brick veneer of first storey resting on concrete basement wall

The following graph compares the BASECALC™ predicted annual energy loss for each of these four insulation/construction configurations for Ottawa, Madison, and San Francisco.



As these results show, BASECALC™ is able to model thermal bridging to the above-grade basement wall and to the first-floor cladding. This is critical in analyzing the effectiveness of exterior insulation and combination insulation, two increasingly popular insulation techniques.

SYSTEM REQUIREMENTS

- 8 MB RAM minimum, 16 MB recommended
- 40 MB hard-disk space
- VGA monitor
- Windows 3.1, Windows NT, or Windows95

Approximate run times:

- 30-40 minutes on a 486 66MHz 16MB RAM computer
- 15-20 minutes on a Pentium 75MHz 16MB RAM computer
- 60-80 minutes on a 486 66MHz 8MB RAM computer

REFERENCES

Mitalas, G.P., 1982, "Basement Heat Loss Studies at DBR/NRC", DBR Paper No. 1045, Ottawa.

Mitalas, G.P., 1987, "Calculation of Below-Grade Residential Heat Loss: Low-Rise Residential Building", ASHRAE Transactions NY 87-03-1.

Beausoleil-Morrison I., Mitalas G., and Chin H., "Estimating Three-Dimensional Below-Grade Heat Losses from Houses Using Two-Dimensional Calculations", to be published in the Proceedings of the ASHRAE/DOE/ORNL/BETEC Thermal Performance of the Exterior Envelopes of Buildings VI Conference, Clearwater Beach, Florida, 1995.