GeoStudio Example File
Heat Loss from Basements

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Introduction

Heat loss through basement walls can substantially influence the thermal regime in the surrounding soil. This example illustrates the use of TEMP3D to simulate heat transfer from a three-dimensional basement foundation. Two scenarios are considered: (1) uninsulated concrete walls; and (2) insulated concrete walls with polystyrene insulation on the exterior and interior wall faces. These analyses provide insight on the overall implication of adding insulation to concrete forms when building basement walls.

Numerical Simulation

The basement is approximately 10 m long by 6 m wide. The geometry is created using the cross-section shown in Figure 1, and reduced to one quarter of the basement using the laws of symmetry for computational efficiency (Figure 2).

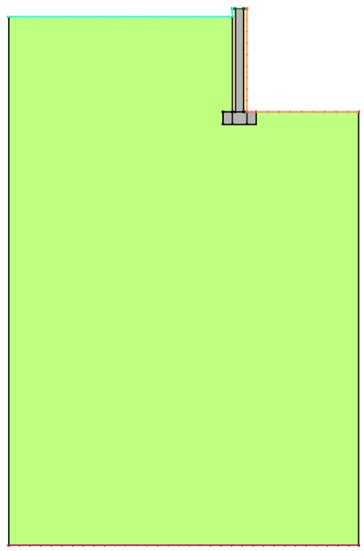

Figure 1. Basement cross-section used for creating the 3D geometry.

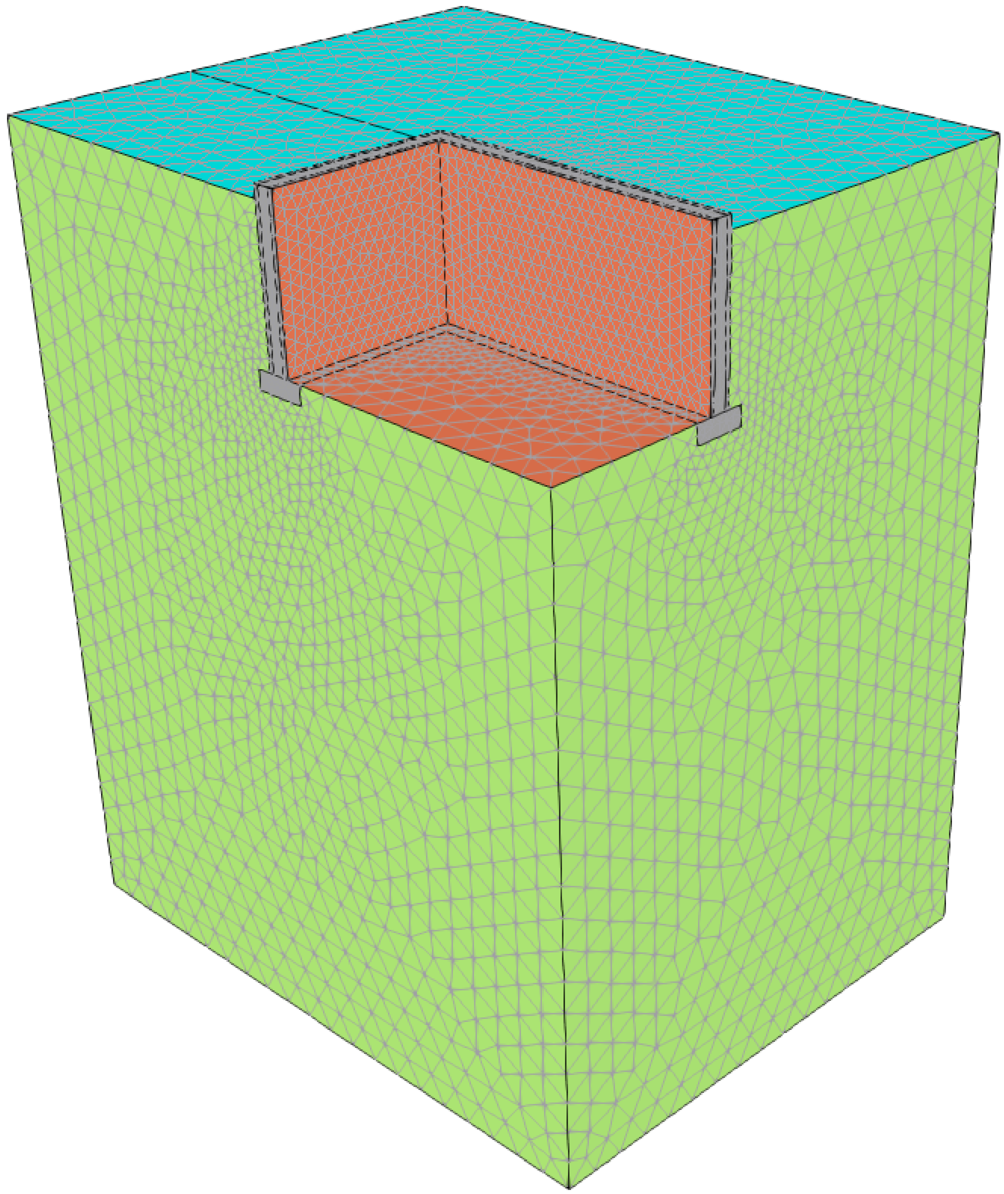

Figure 2. Domain and mesh configuration.

As shown in Figure 3, two transient thermal analyses are associated with the 3D geometry. The first analysis represents the scenario without insulation, while the second includes insulation. Both analyses simulate heat transfer over a 100-day period using an exponential time stepping scheme. A 1D transient thermal analysis is also included in the project file to simulate the soil temperature without the presence of the basement.

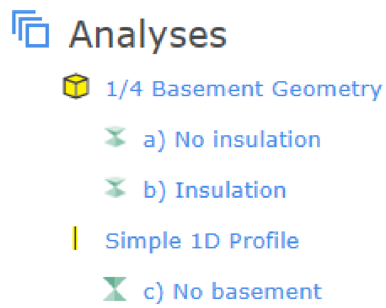

Figure 3. Project tree including the geometries and associated analyses.

Material Properties

The concrete and expanded polystyrene (EPS) foam insulation are defined with the simplified thermal material model using the values provided in Table 1. The insulation is applied to the interior and exterior of the basement walls in the second transient analysis. The clay is defined with the full thermal material model using the normalized unfrozen volumetric water content function shown in Figure 3. The initial temperature throughout the domain is established by setting the activation temperature equal to 3˚C in all materials definitions.

Table 1. Material properties.

Material	Thermal conductivity	Unfrozen volumetric heat capacity	Frozen volumetric heat capacity
	(J/s/m/ºC)	(kJ/m³/ºC)	(kJ/m³/ºC)
Concrete	1.5	2000	2000
EPS insulation	0.04	0	0
Clay	1.9	2300	1900

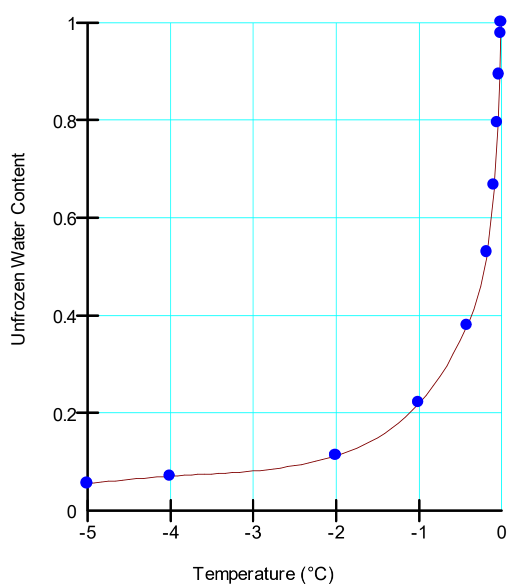

Figure 4. Normalized unfrozen volumetric water content function of the clay.

Boundary and Initial Conditions

The boundary conditions applied in both analyses are the same. A temperature boundary condition of 20°C is applied to the faces representing the basement interior (orange faces, Figure 2). The bottom of the domain represents the depth at which temperature remains constant over time, with a temperature boundary condition of 3°C. Finally, a temperature of -5°C is applied at the ground surface to represent the average winter temperature in central Canada.

Results and Discussion

The temperature contours at the end of the first analysis illustrate the influence of the uninsulated basement on the surrounding soil. As shown in Figure 5, the temperature at a reference point, 2 m below the ground surface and 1 m away from the basement wall, is 8°C on day 100. These contours change significantly in the presence of insulation. As shown in Figure 6, two layers of insulation on the basement walls provide a substantial barrier to lateral heat loss, and thus a much lower temperature (4°C) is observed at the reference point. Note that the temperature gradients across the insulation are very high so the contours appear to be black in these regions.

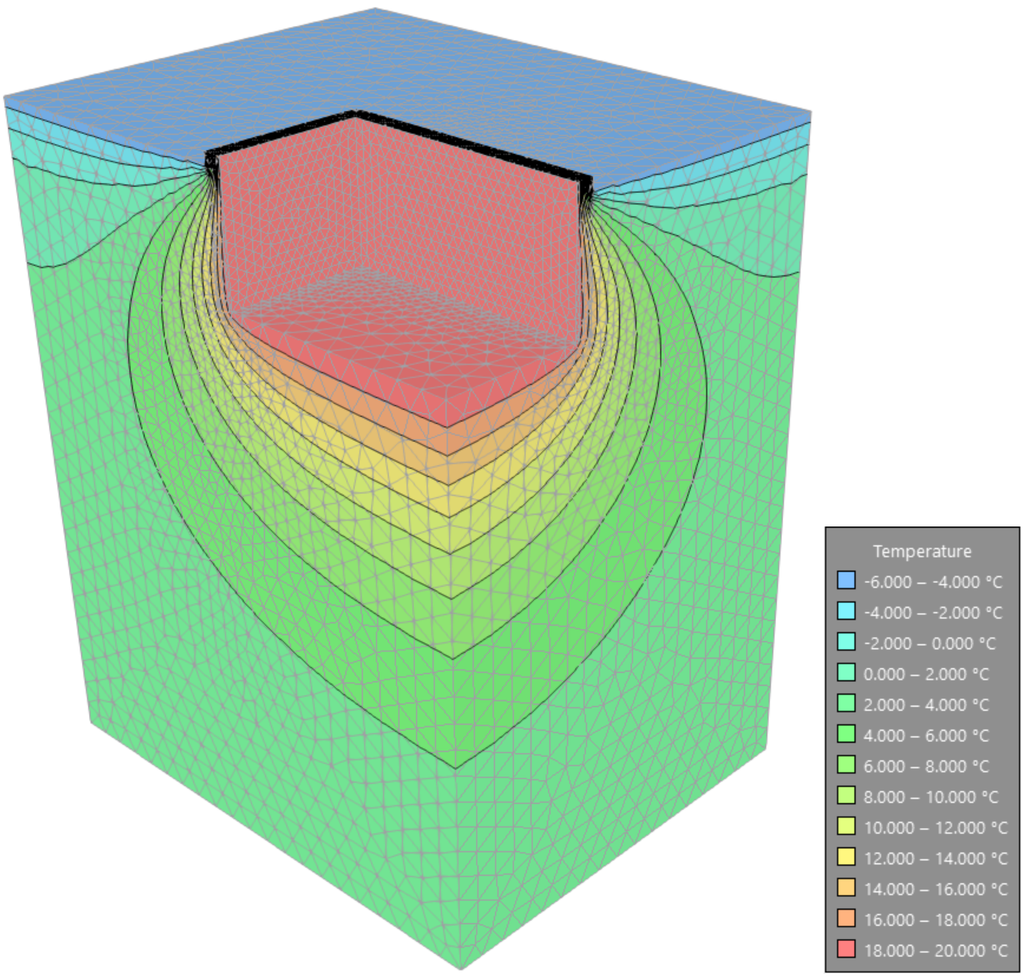

Figure 5. Temperature contours on day 100 for the uninsulated basement.

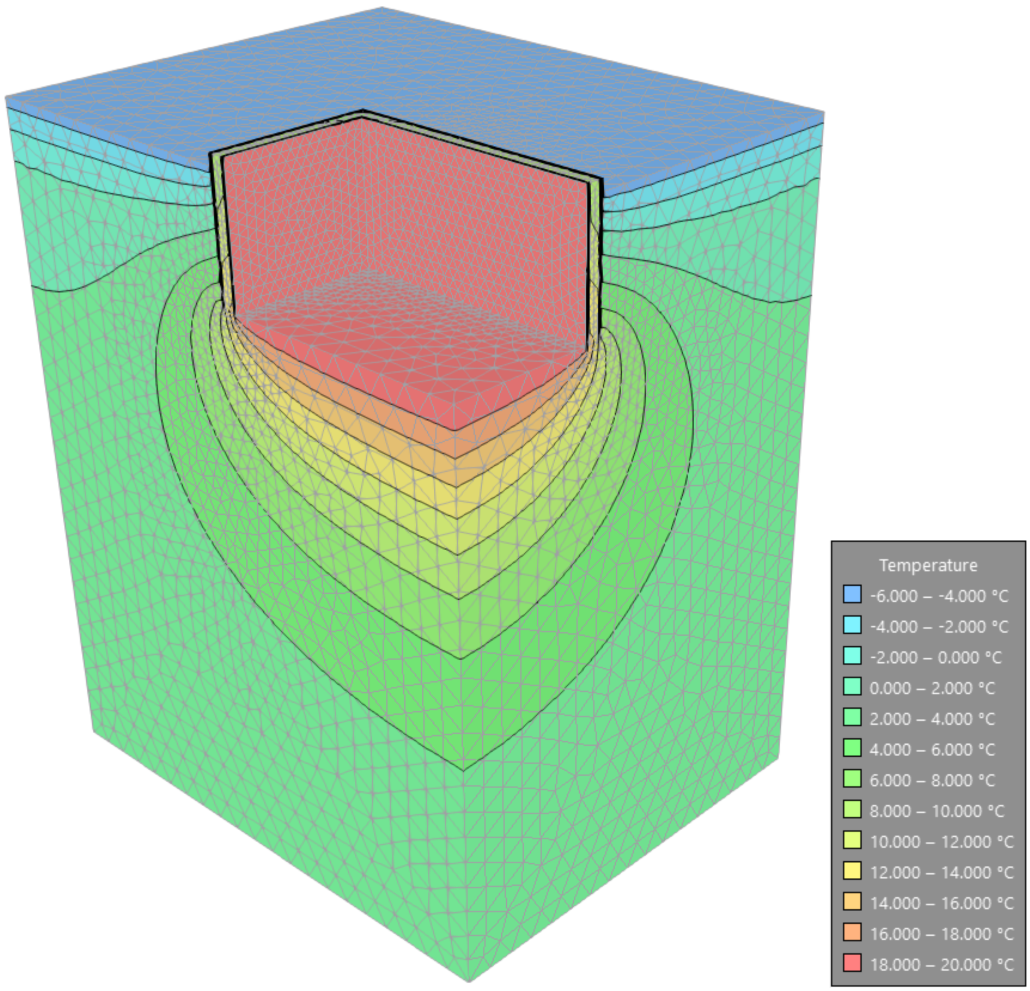

Figure 6. Temperature contours on day 100 for the insulated basement.

Figures 7 and 8 show the temperature profiles on the exterior of the basement walls at the centre and corner of the basement on different days. As expected, temperatures at the basement corner are generally lower than temperatures at the basement centre, and the differences in temperature are greater in the case of the uninsulated basement. The temperature profile from the 1D analysis is also included in Figures 7 and 8 to illustrate the temperature trends with depth in the absence of a basement. As expected, the scenario without a basement leads to lower ground temperatures.

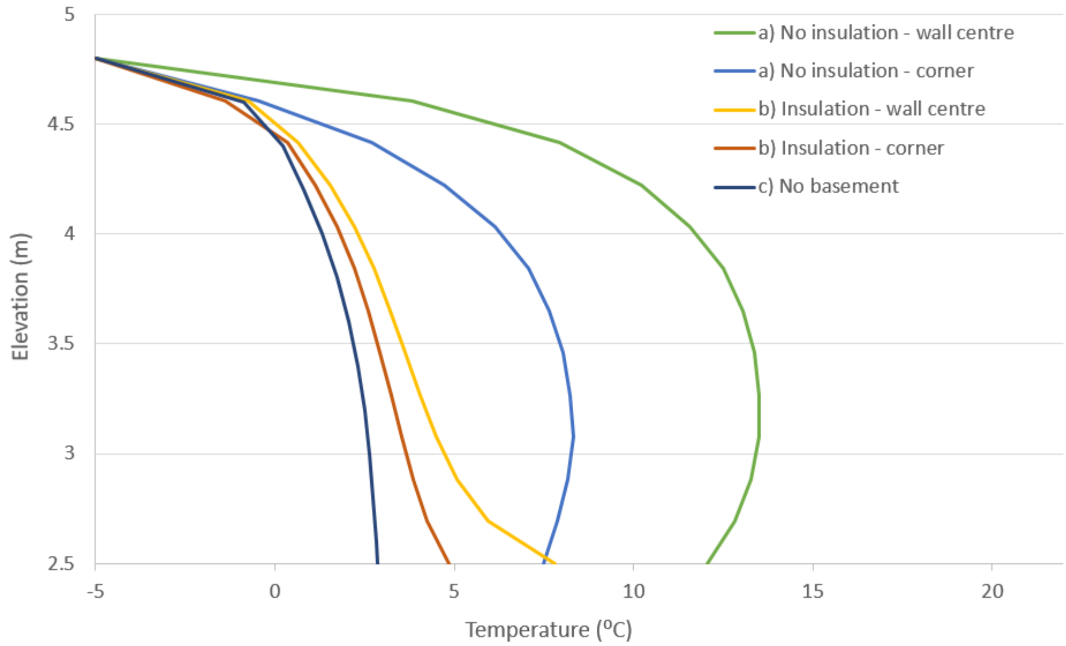

Figure 7. Temperature profiles on day 8.

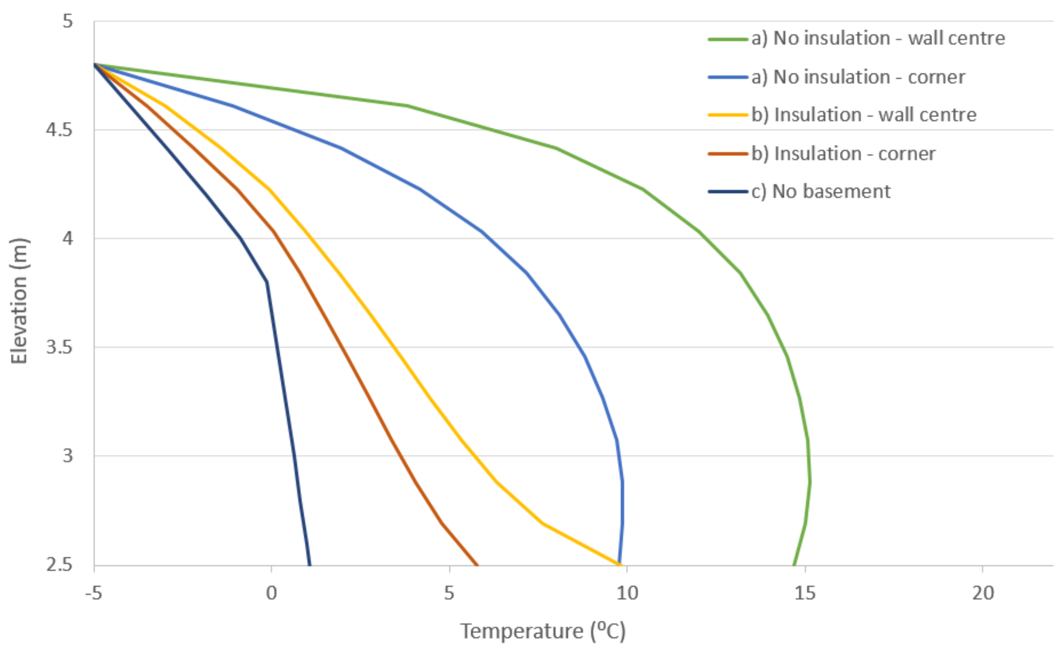

Figure 8. Temperature profiles on day 100.

The heat rate (or heat loss) across the faces of both the uninsulated and insulated basement is greatest at the beginning of the analysis and decreases exponentially with time (Figure 9). These results suggest that the heat transfer reaches, or is close to reaching, steady-state conditions. At this point, the heat rate across the faces of the uninsulated and insulated basement was 1.0 kJ/s and 0.3 kJ/s, respectively. It is important to recall that this is the heat rate across one quarter of the surface area of the basement. Multiplying these values by four results in total heat rates of 4.1 and 1.4 kJ/s for the uninsulated and insulated basements, respectively. It is no great surprise that the long-term heat loss from the uninsulated basement is substantially greater than the heat loss from the insulated basement.

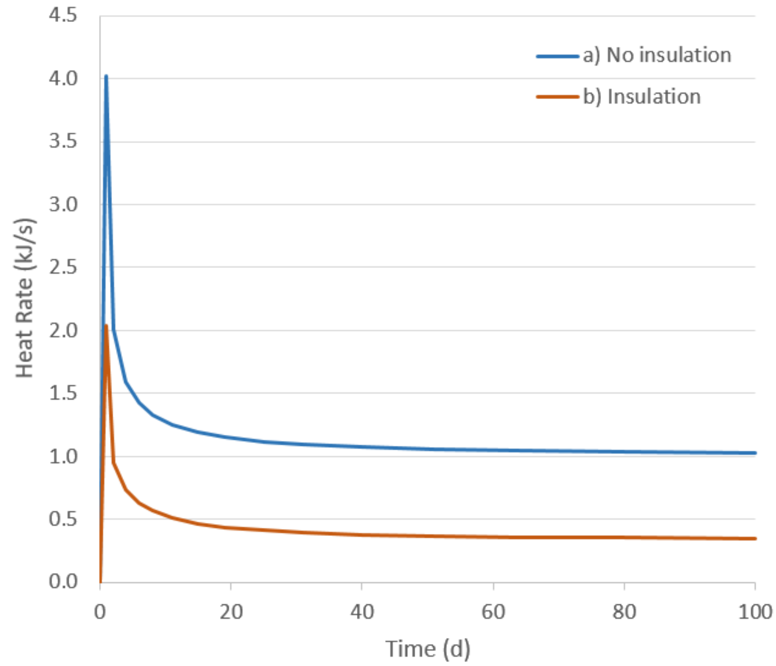

Figure 9. Heat rate across the basement faces.

Figure 10 shows the cumulative energy transfer across the basement faces. Multiplying these values by four results in the total cumulative energy transfer (or loss) from the basement.

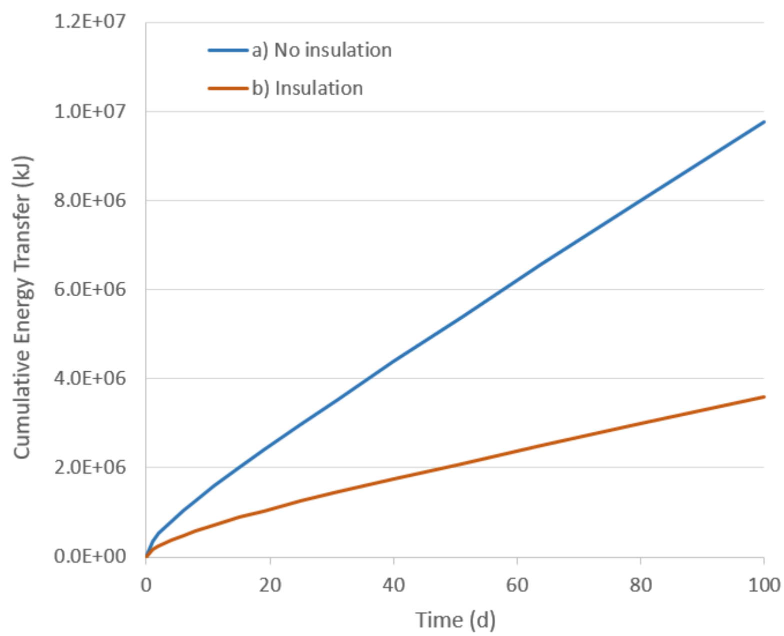

Figure 10. Cumulative energy transfer across the basement faces.

Summary and Conclusions

Heat loss through basement walls and floors was found to have a significant impact on surrounding soil temperatures. The impact was different at the basement corners compared to the centre of the basement walls, which highlights the importance of conducting this type of analysis using a three-dimensional geometry. This example also confirmed that heat loss significantly decreases when insulation is present on the inside and outside of the concrete walls.