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Unsteady-state thermal analysis of insulated slab-on-ground foundations: impact of edge insulation on ground temperature distribution

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INTRODUCTION & AIM

Slab-on-ground foundations are common in residential buildings, with the slab edge being a critical zone where ground freezing may occur if insulation is poorly designed. Previous work by the author used steady-state simulations to study how edge insulation geometry affects ground temperature and frost risk, but steady-state models neglect soil thermal inertia and seasonal temperature changes.

Aim:

- to perform unsteady-state simulations of insulated slab-on-ground foundations for the Poznań climate,
- to compare transient and steady-state results and assess whether steady-state analysis is sufficiently accurate and safe for design.

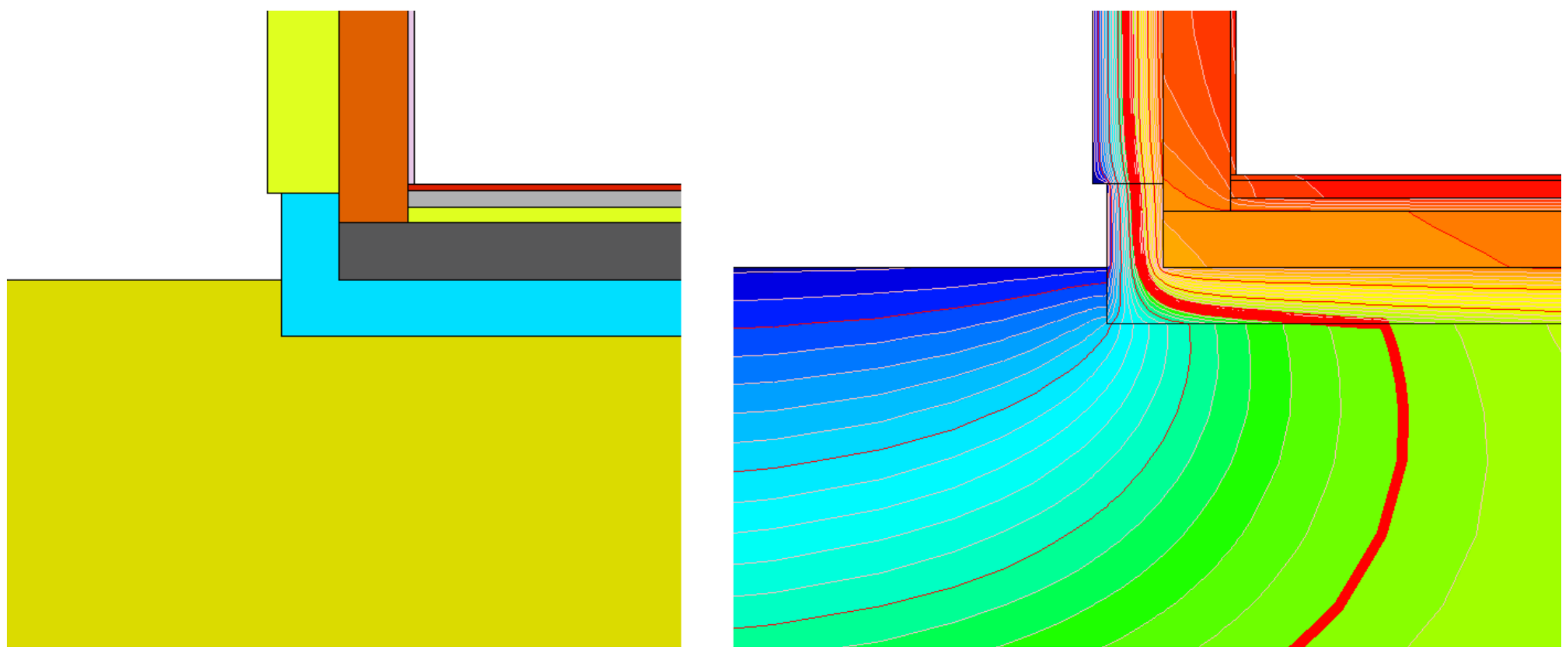

Fig. 1. Cross-section of the slab-on-ground foundation without edge insulation (left) and resulting ground temperature field for winter design conditions with highlighted 0 °C isotherm (right). The freezing of the soil beneath the slab indicates a risk of frost heave.

METHOD

A unsteady-state heat transfer analysis was performed for a slab-on-ground foundation with XPS edge insulation using VOLTRA (Physibel), a numerical tool for time-dependent heat transfer. The model included the concrete slab, XPS insulation and surrounding soil, while the following insulation parameters were varied: thickness, length extending into the ground and inclination angle relative to the slab edge. Boundary conditions assumed a heated interior and Poznań climate data, with simulations run over two years and results compared with previous steady-state analyses for the same configurations.

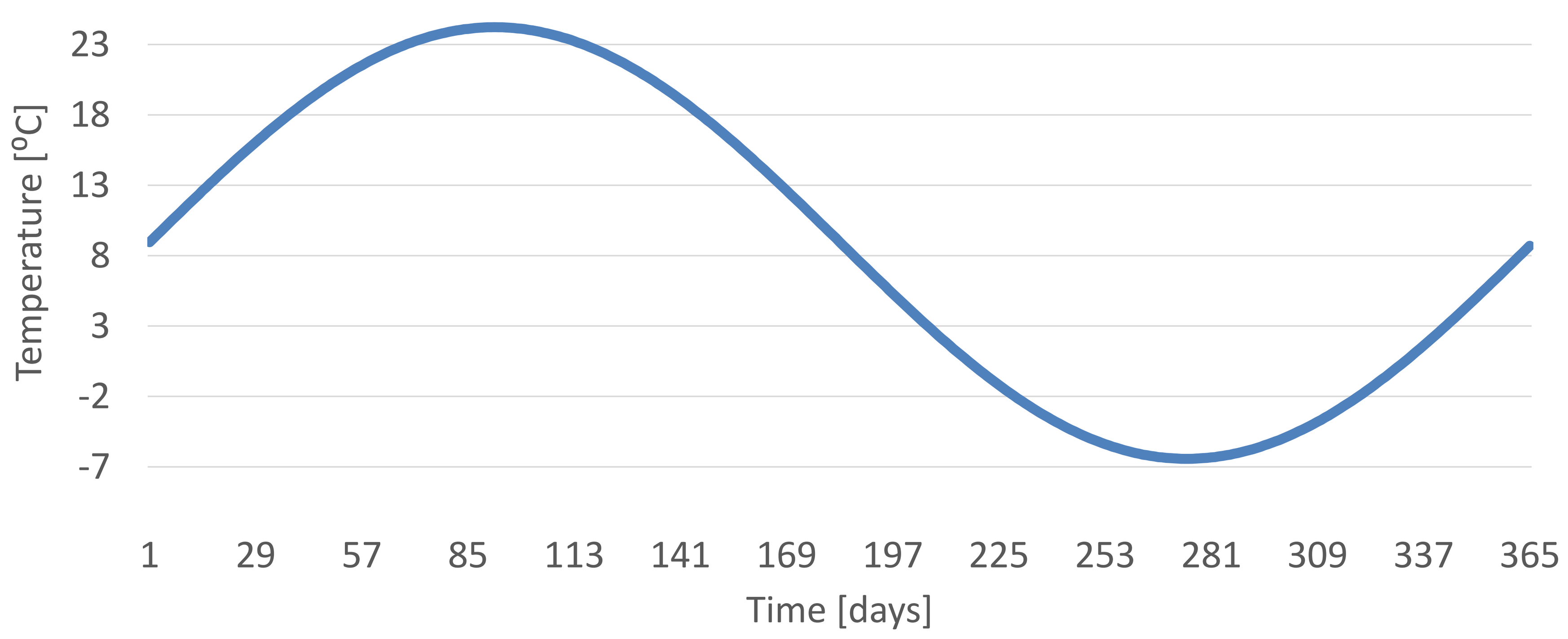

Fig. 2. Sinusoidal outdoor air temperature boundary condition derived from the 20-year freezing index for the Poznań location.

RESULTS & DISCUSSION

Unsteady-state simulations predict higher minimum soil temperatures under and next to the slab than previous steady-state analyses, so the steady-state approach is conservative and provides an extra safety margin against ground freezing. The influence of insulation thickness, length and inclination is similar in both approaches. Inclined edge insulation is the most effective configuration, and well-calibrated steady-state simulations with appropriate boundary conditions give reliable, slightly conservative results for design.

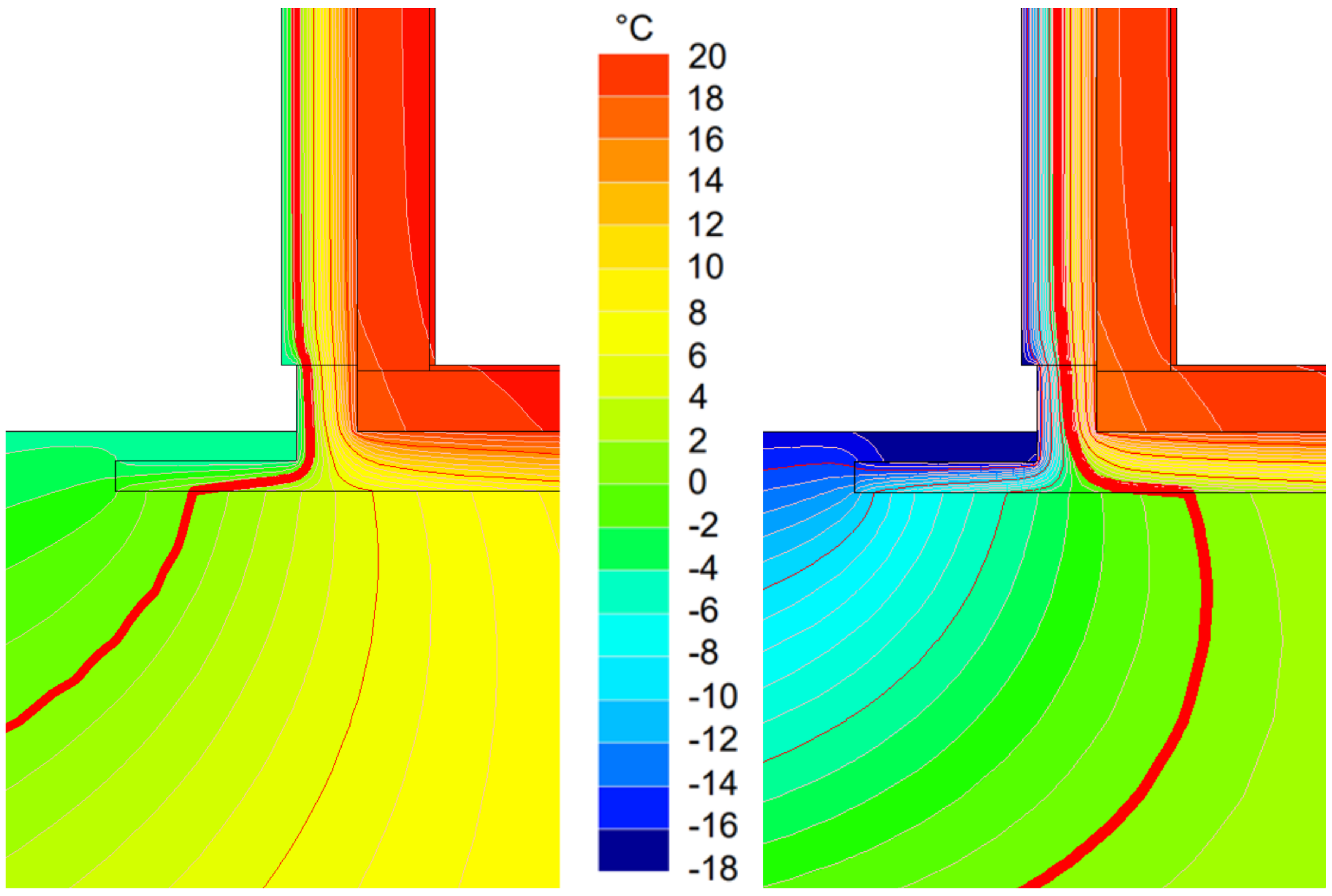

Fig. 3. Ground temperature isotherms for a slab-on-ground foundation with edge insulation from unsteady-state (left) and steady-state (right) simulations for winter design conditions. In both cases the 0 °C isotherm is highlighted, showing higher soil temperatures and a smaller frozen zone in the unsteady-state analysis.

CONCLUSION

- Unsteady-state simulations for the Poznań climate show higher ground temperatures than steady-state models, so steady-state analysis is on the safe side.
- The effect of insulation thickness, length and inclination is qualitatively the same in both approaches, with inclined edge insulation remaining the most effective configuration for limiting soil freezing risk with reasonable insulation use.
- For typical design cases, properly set steady-state simulations are sufficient to design edge insulation for slab-on-ground foundations.

REFERENCES

[1] Smoczyk, M., Ksit, B., Szymczak-Graczyk, A. (2025). Numerical analysis of the ground temperature function depending on edge thermal insulation parameters for shallow slab foundations. *Energy*, 314, 134221.

[2] PN-EN ISO 13793Thermal performance of buildings - Thermal design of foundations to avoid frost heave