Using Multiphysics Simulation to Prevent Building Damage

In extreme climates, moisture and temperature changes can damage building foundations. Vahanen Group is using multiphysics simulation to equip construction teams with assessments that help prevent frost damage and maintain safe building structures.

BY LEXI CARVER

Though they often go unnoticed, underground insulation and heating systems prevent critical damage to concrete building foundations, and keep occupants safe and warm indoors. Since concrete is porous, water and contaminants can enter the foundation. When the foundation or the soil underneath freezes, this can cause structural damage such as cracking. Some older buildings are protected from this by insulation, while others are protected by heated pipes that travel from the boiler to the building's indoor heating units.

Ongoing damage can lead to serious risks, such as the buckling or collapse of a building. To address the challenges of cold and moisture, Vahanen Group (Espoo, Finland), a company specializing in building services such as quality assessments and construction recommendations, analyzes the potential for frost damage in buildings being considered for renovation. Their work is especially vital in cases where renovations are necessary due to existing damage, for instance, where heating systems and pipes need to be replaced.

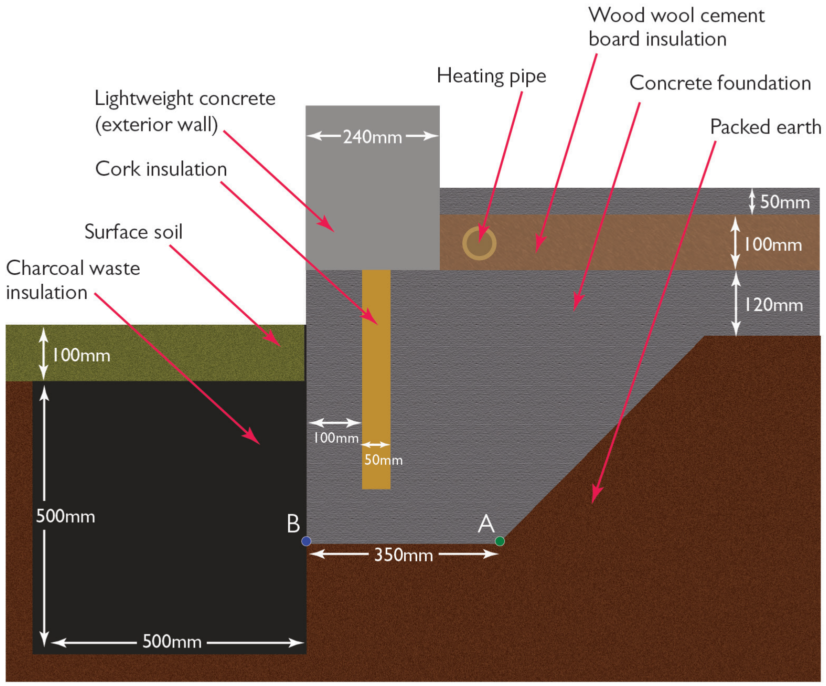

FIGURE 1. Schematic of the building model geometry. The heating pipe runs from the boiler to the indoor heating units, and keeps the foundation warm at the same time.

WHAT'S THE BEST WAY TO INSULATE A BUILDING?

Pauli Sekki, building specialist at Vahanen, is using the simulation capabilities of COMSOL Multiphysics® to perform risk assessments — his goal is to discern whether certain renovations to foundations or heating systems would require adding external frost insulation. If added unnecessarily, this would waste valuable money, time, and work.

For one project, Sekki's COMSOL model (see Figure 1) includes the foundation, levels of loose soil and packed earth, several types of insulation, lightweight concrete walls, and a pipe from a heating system passing underneath a building near the wall and foundation.

First Sekki simulated temperature changes based on local climate data for Helsinki, Finland. Government frost table data provides annual total freezing degree hours (FDH), a quantity representing the number of degrees that the daily mean temperature is below 0°C. (For example, for a day with an average temperature of -5°C, the FDH is 5 degrees x 24 hours = 120.) An annual total sums the FDH from each day in a year (the annual freezing index), typically about 14,000 FDH for Helsinki.

From the existing data, Sekki generated a "critical freezing" quantity to account for abnormally cold winters that occur, on average, every fifty years (with about 40,000 FDH). Given the importance of building strength and longevity, any renovations would have to withstand not only a typical winter climate, but also these rarer, harsher conditions. "Design and construction teams turn to Vahanen to verify that their renovation plans are safe, will last, and are the best use of the available materials and resources," Sekki explained. "And we turn to COMSOL for that information."

In this example, he needed to determine whether renovations including the complete removal of a damaged heating pipe would endanger the building. Was the existing insulation sufficient? To answer this question, he modeled heat transfer in the pipe, the insulation, and the foundation. "Tools in COMSOL Multiphysics are very easy to use for this kind of complex model," he commented. "The almost unlimited possibilities for setting boundary conditions were a huge advantage."

PREDICTING THE POTENTIAL FOR FROST DAMAGE

Sekki used his simulation to predict temperatures at the two lowest corners of the concrete foundation (points A and B in Figure 1). He investigated three cases: the original structure, the structure after heating system renovations (where heat transfer from a pipe would no longer occur), and the structure after renovations that additionally replaced damaged wood wool cement board (WWCB) with expanded polystyrene (EPS) insulation.

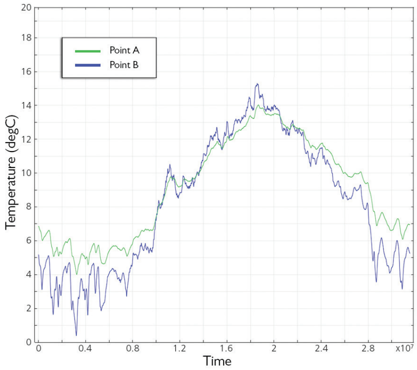

FIGURE 2. Simulation results showing temperatures over a typical year (14,000 FDH) for the renovated building with EPS insulation added.

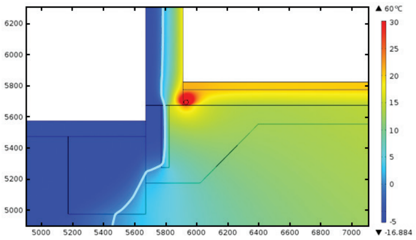

FIGURE 3. Temperature distribution for the unrenovated building for extreme winter conditions (40,000 FDH) occurring every 50 years.

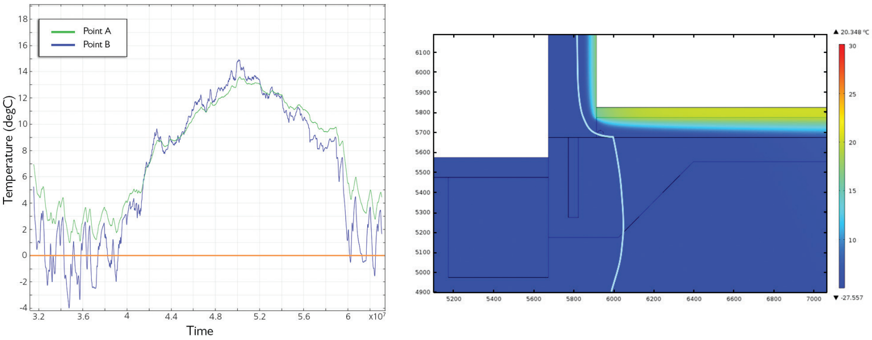

FIGURE 4. Temperature results (40,000 FDH case) for the building after renovations and additional EPS insulation. The orange line (line graph) and vertical contour (surface plot) indicate 0°C.

For a typical year in Helsinki, the ground stayed warm enough to prevent damages to the building in its original state as well as after heating system renovations. However, after the WWCB insulation was replaced with EPS, the ground near the foundation dipped to 0.5°C (see Figure 2), low enough to be a concern. "The new EPS-insulated structure would have been at risk for frost damage," Sekki said. "Thankfully, multiphysics simulations are helping us avoid that."

KEEPING STRUCTURES STRONG FOR THE WORST WINTERS

After simulating the building during a longer winter, he found that only the foundation of the original structure stayed safely above freezing temperatures (see Figure 3).

The ground around the foundation of the renovated structure with WWCB dipped to -2°C in the simulation. The foundation of the renovated structure with the replacement-EPS insulation dipped even farther, to -4°C. This meant removing the heating pipe would risk serious damage to the building foundation (see Figure 4). It would be necessary to install additional insulation at the same time.

PRESERVING STRUCTURAL INTEGRITY THROUGH SOUND RECOMMENDATIONS

Sekki is using his findings to ensure safe building renovations in climates like Helsinki. Using simulation, he is able to assess the heating needs of structures with complicated geometries, and can test different insulation materials and thicknesses to make sure the techniques he recommends are safe and sufficient. To further their aims of providing strong support to construction teams, Vahanen is also using COMSOL to model transient heat and moisture transport, and indoor air flow. "Thanks to simulation, we can make good recommendations to our customers," Sekki remarked, "and prevent changes that would ultimately cause structural damage." ■

Pauli Sekki, building physics specialist for Vahanen Group.