Simulation of Heat Transfer during Artificial Ground Freezing Combined with Groundwater Flow

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Introduction: The principle of artificial ground freezing (AGF) method is to circulate a fluid refrigerant (ca. -30℃) through a pre-buried pipe network in the subsurface in order to form a freezing wall for construction strengthening. The main physical process is a transient heat conduction phenomenon with phase change.

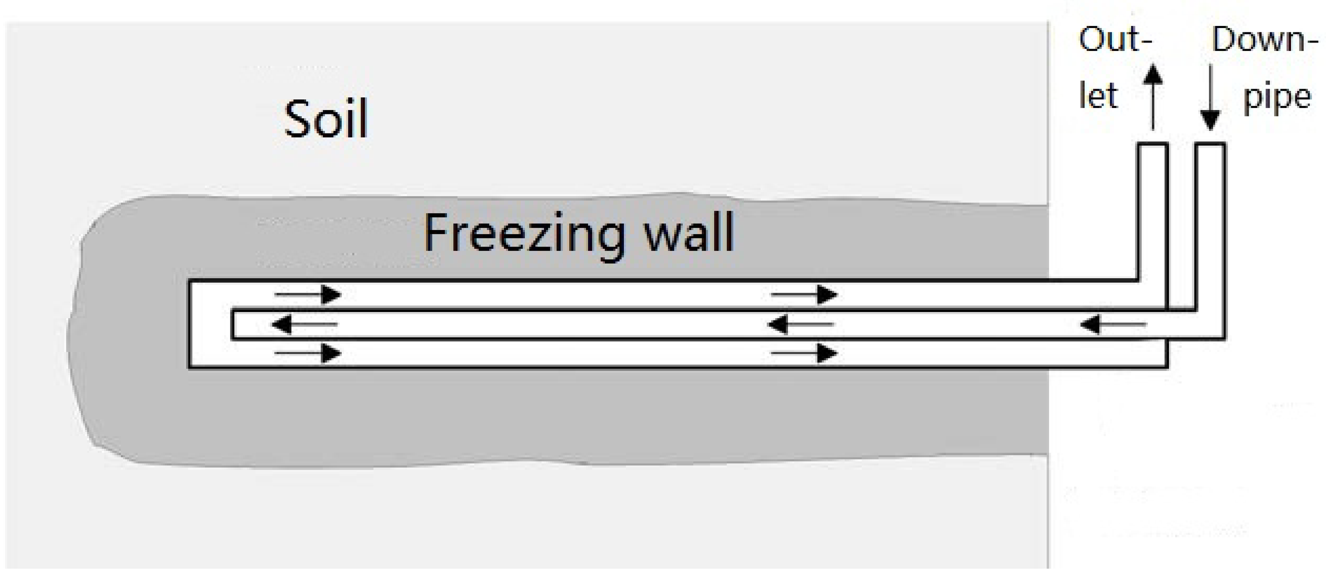

Figure 1. Schematic diagram of AGF process

Computational Methods: In a saturated aquifer, the heat transport process mainly includes heat conduction, heat convection and the release of latent heat in AGF activities. The temperature field will also be affected by the flow of groundwater.

$$C_{eq}\frac{\partial T}{\partial t}-\nabla[\lambda_{eq}\nabla T]+C_f\vec{u}\nabla T-\rho_w L\frac{\partial S_w}{\partial T}=Q_G$$

$$(1-\varepsilon S_i)S_{OP}\frac{\partial p}{\partial t}+\nabla[-\frac{k_r K\rho}{\mu}\cdot(\nabla p+\rho_w g\nabla D)]-\varepsilon(\rho_w-\rho_i)\frac{\partial S_i}{\partial t}=Q_S$$

Based on, we used a 2D model to simulate this engineering. The lateral pipe temperature are obtained by fitting the measured temperature.

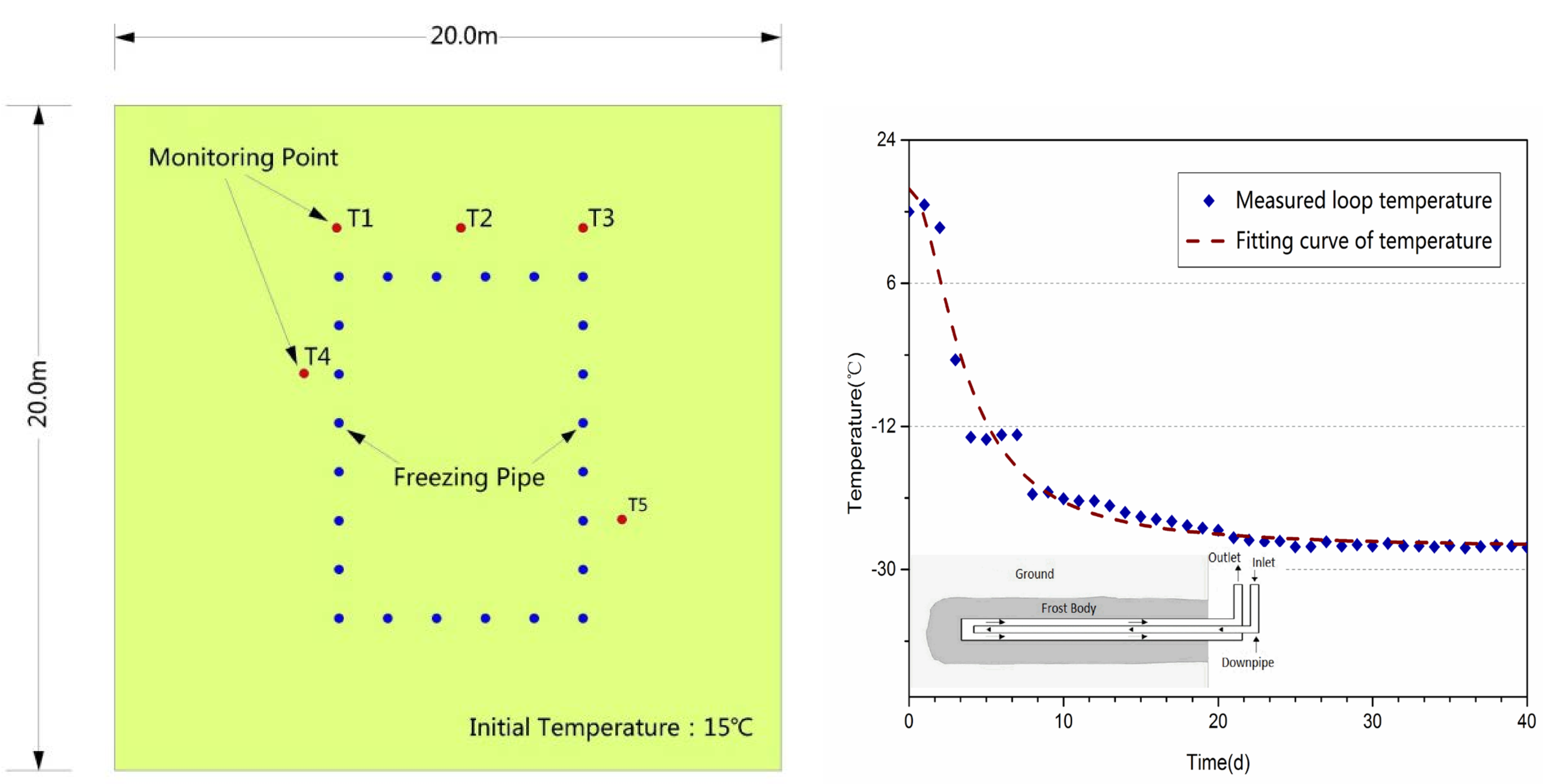

Figure 2. Model geometry and boundary condition

Results: The temperature map show that the cold temperature from freezing pipes is mainly conducted to downstream and has less impact on upstream. The zone of low relative permeability is agreed with the shape of freezing wall.

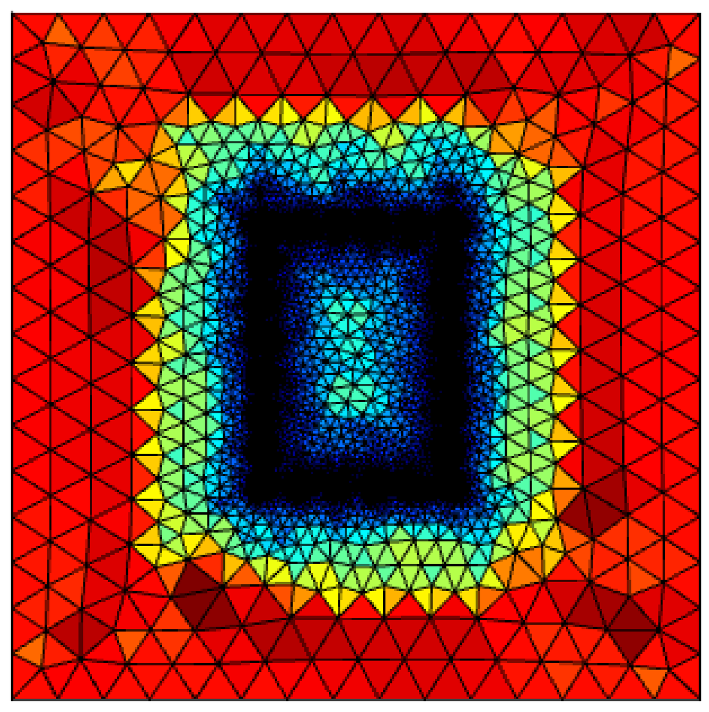

Figure 3. Adaptive grid

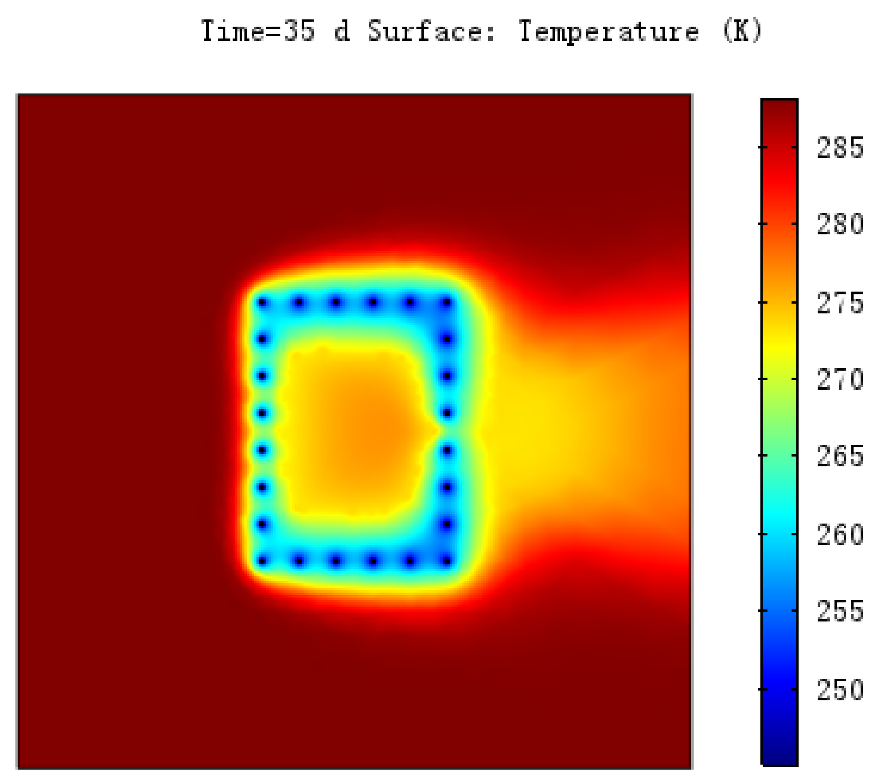

Figure 4. Temperature at 35^d

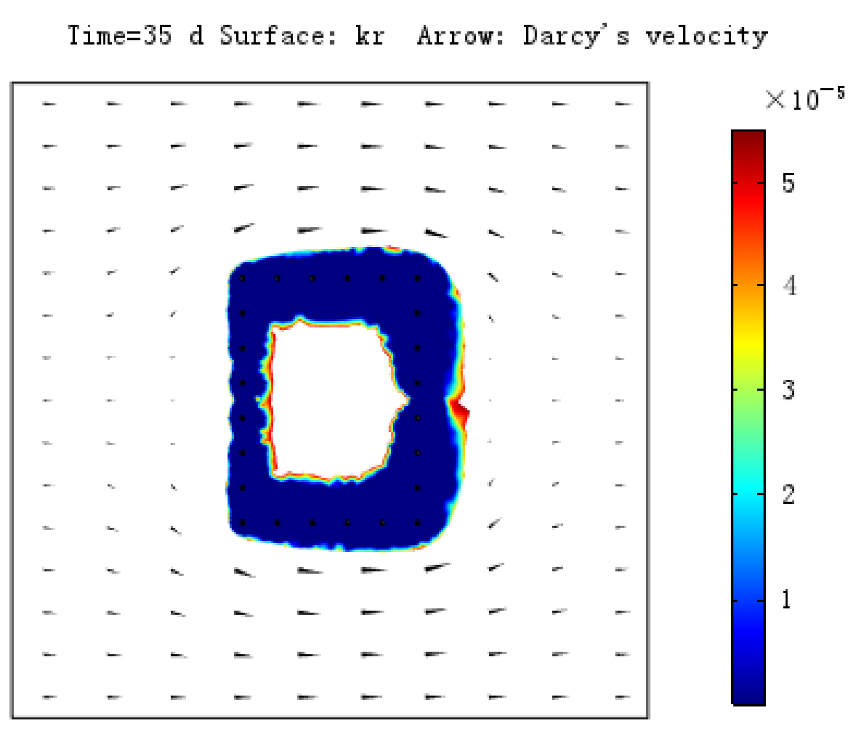

Figure 5. Relative permeability at 35^d (T<0)

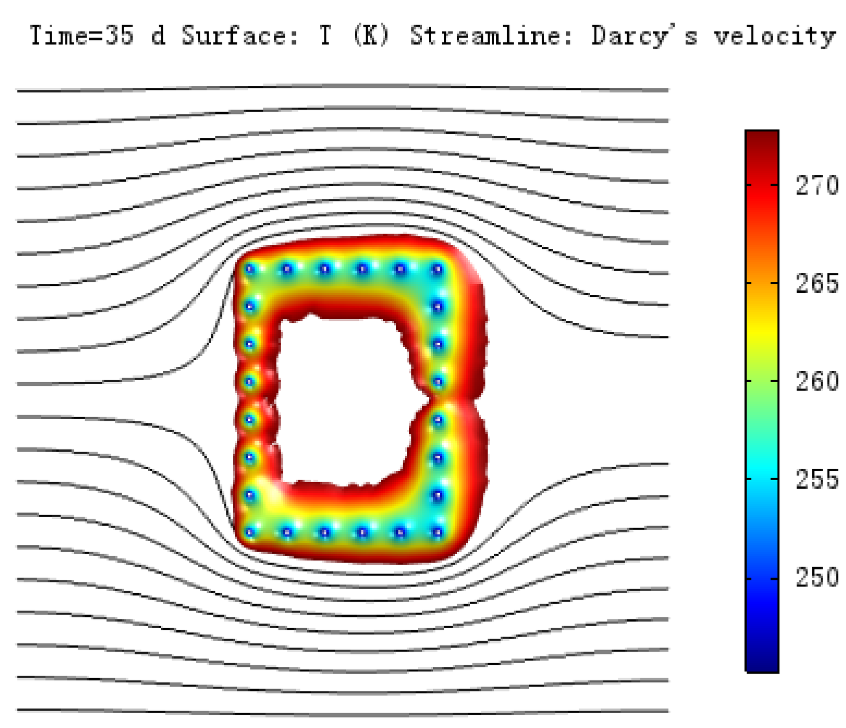

Figure 6. Freezing wall at 35^d (T<0)

Conclusions: In this simulation, the seepage effect has a great influence on temperature distribution and the formation of the frozen wall. In the next step, we hope to further develop this model and applied in different AGF cases.

References:

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3. 3. Vitel M, Rouabhi A, Tijani M, et al. Modeling heat transfer between a freeze pipe and the surrounding ground during artificial ground freezing activities. Computers and Geotechnics 63 99-111 (2015).