VERIFIKACIJA MODELA ENERGETSKIH ŠIPOVA

ENERGY-PILE MODEL VERIFICATION

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Opremanje temeljnih šipova cevovodom za tečni krug omogućava korišćenje povoljnog toplotnog kapaciteta tla za grejanje i hlađenje zgrada po niskim troškovima. Energetske performanse energetske gomile u tlu su privremeni fenomen koji zavisi od mnogih parametara, a koji bi se mogao ispitati pomoću računarskog modela. Prilog se bavi opisom i verifikacijom novog numeričkog računarskog softvera zasnovanog na pojednostavljenom 2D i 2D rotacionom simetričnom modelu provodljivosti toplote koji je razvijen za modeliranje energetskih šipova.

Ključne reči: *energetski šip; razvoj softvera; verifikacija; numerički model; računski mrežni generator*

Equipping the foundation piles with a liquid circuit pipeline makes it possible to use the advantageous thermal capacity of the soil for heating and cooling buildings at low cost. The energy performance of the energy-pile in a soil is a transient phenomenon dependent on many parameters, which could be investigate by a computational model. The contribution deals with the description and verification of a new numerical computational software based on a simplified 2D and 2D rotational symmetrical heat conduction model being developed for energy-piles modeling.

Key words: *energy-pile; software development; verification; numerical model; computational mesh generator*

1 Introduction

Energo-pilot (Epilot) – thermally activated pilot – is a vertical foundation structure in which a liquid heat exchanger is located, through which heat is transferred between the soil and the heat transfer medium. The main advantage of the energy pilot, compared to heat boreholes, is significantly lower installation costs. On the contrary, the main disadvantage is, due to the smaller lengths of energy-piles than heat boreholes, their lower power. Energy pilots can be used in combination with a water / water or water / air heat pump, or in the so-called "free cooling" mode. The floor plan of the piles is based on static calculations, and from an energy point of view we can only decide on the geometry of the liquid pipeline when dimensioning.

The power of energy-piles depends mainly on the area of the pipe in the pile, therefore the highest power is achieved with the pipe wound into a spiral. In general, there are two ways of modeling the thermal processes taking place in the epilote - using analytical models and using numerical models. Analytical models contain a number of simplifications, which significantly reduce their computational complexity [3], [4]. In contrast, numerical models can relatively better simulate more complex geometries and physical processes taking place in the pilot and surrounding soil. Numerical models are generally more computationally intensive than analytical models.

In general, 3D-dimensional models are computationally demanding, so 2D, 1D [2], [5] analytical or hybrid models are more commonly used in heat exchanger design. The developed analytical methods of energy-pilot simulation were presented in [6].

The goal of the new model implemented in the Epilot software was to reduce the computational complexity as much as possible, so that the model would be competitive in this respect for analytical models and at the same time make it possible to solve more complex physical processes.

2 Model description

The computational model of the thermal behavior of the energy pile is based on a linear or nonlinear numerical solution of stationary or non-stationary heat conduction by the finite volume method according to [10]. The software is primarily focused on energy-pilot modeling, but it can also be used for modeling thermally-activated foundations or foundation walls (collectively referred to here as energy-walls). The computational domain of the energy-pile / energy-wall has thus been simplified to a 2D rotationally symmetric (RS) / planar (PL) computational domain for a preset geometric arrangement of the characteristic energy-pile / energy-wall.

The following predefined boundary conditions can be selected for all surfaces of the computational domain: Drichlet, Neumann, Robin, Neumann-Robin.

According to the arrangement of the descending and ascending channel we call the double helix "Duplex Coil" (DC).

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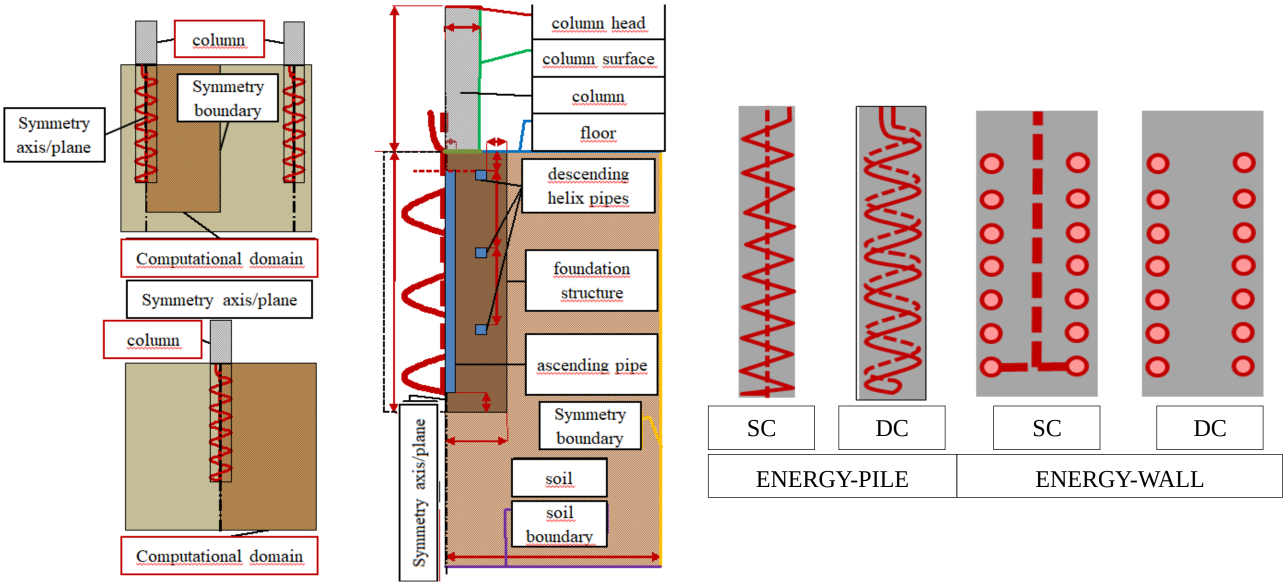


Computational domain and liquid pipeline geometry variants description

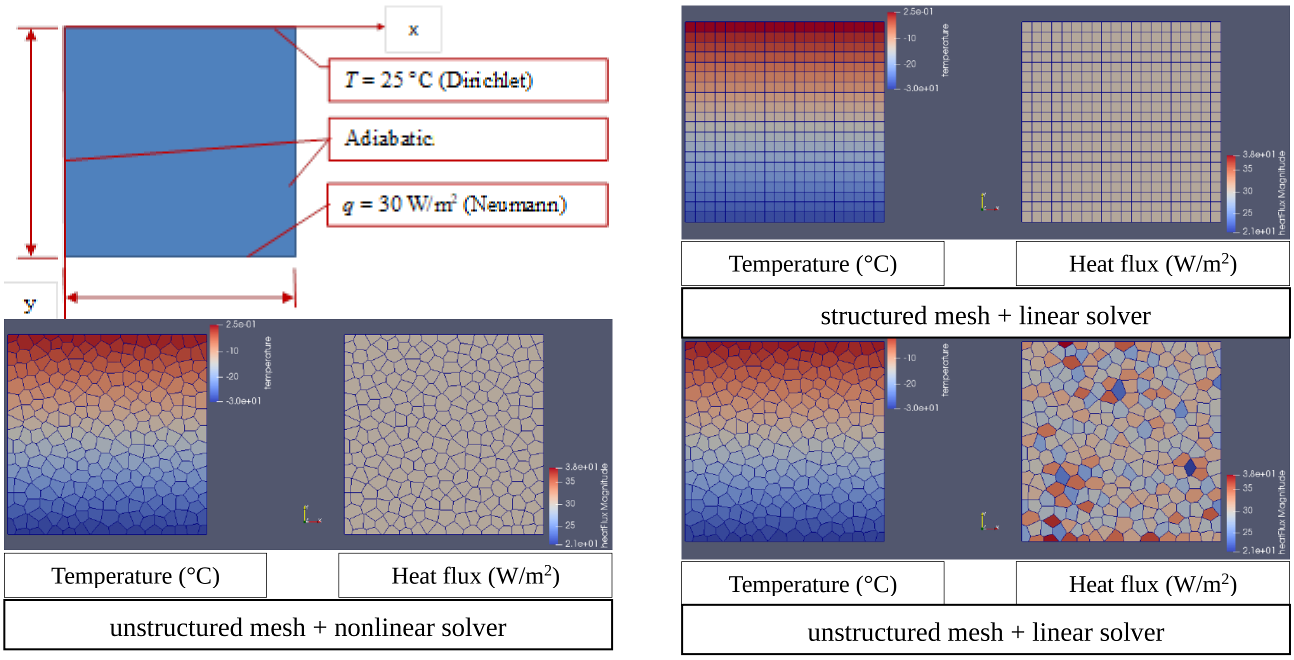
The type of computer mesh plays an important role in the time-consuming nature of numerical calculation. When using structured equidistant meshes, the number of computational cells is large, so the optimal solution may be the use of purely unstructured meshes or mixed meshes. Polyhedral meshes and divided Cartesian nets called "Snappy hex mesh" and mixed nets were developed, implemented and tested. Such types of networks will then make it possible to solve this type of problem with the number of cells in the order of hundreds and thus achieve approximately 100 times less number of cells and thus save computational time.

3 Verification

Verification of the numerical solution was performed for stationary and non-stationary solutions by comparison with CalA 4.0 software [11] (verified according to EN ISO 1021 and ISO 11855 [13]) or software ANSYS Fluent [12] in the following cases.

3.1 Verification case 1 – the type of computer mesh with respect to the used linear / nonlinear solver

This subchapter verifies the applicability of a linear solver to general unstructured networks.

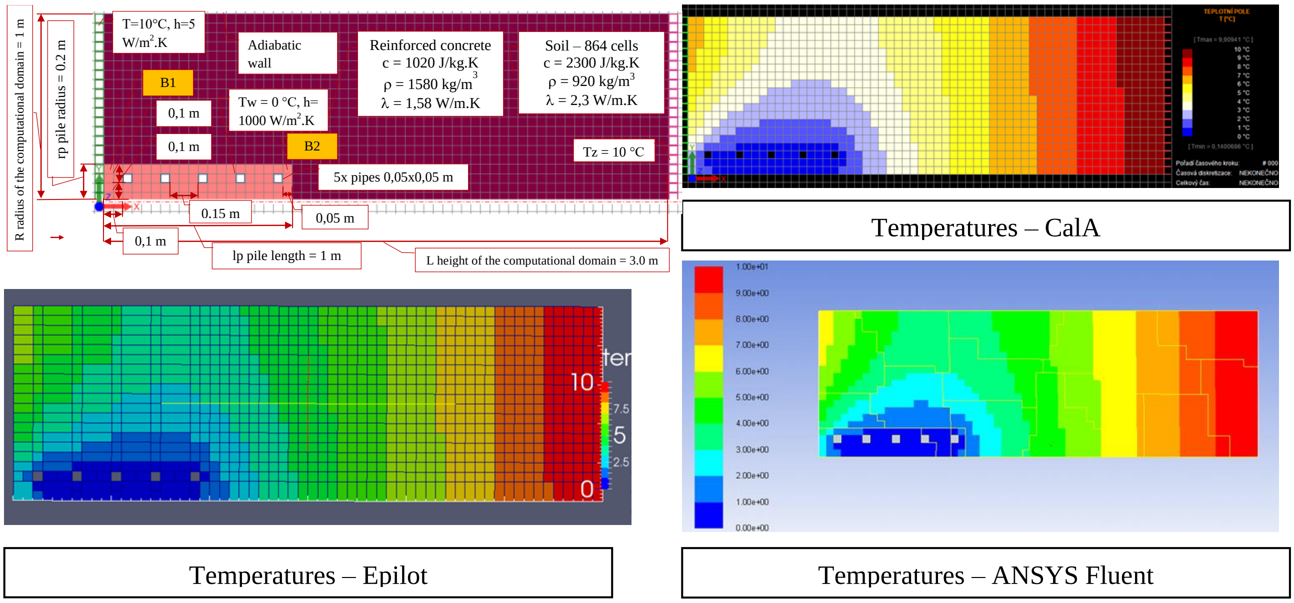


Verification case 1 – Definition and results

In the case of meshes whose edges are not perpendicular to the joints of the centers of gravity of adjacent volumes, a nonlinear solver must be used to eliminate this error.

3.2 Verification case 2 – the stationary task by software CalA 2D - PL

This is a steady verification on the case of 2D planar computational domain software in CalA and ANSYS.

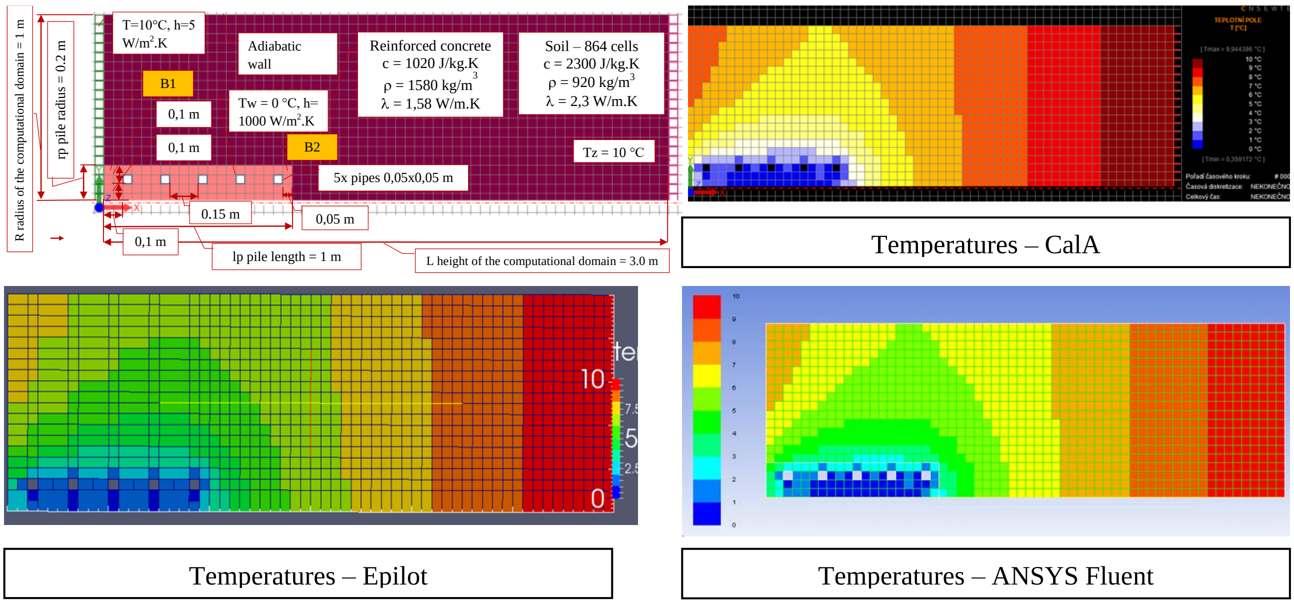


Verification case 2 – Definition and results

There is a good agreement between presented methods and Epilot software.

3.3 Verification case 3 – the stationary task 2D - RS

This is a steady verification on the case of 2D rotational-symmetrical computational domain in software CalA and ANSYS.

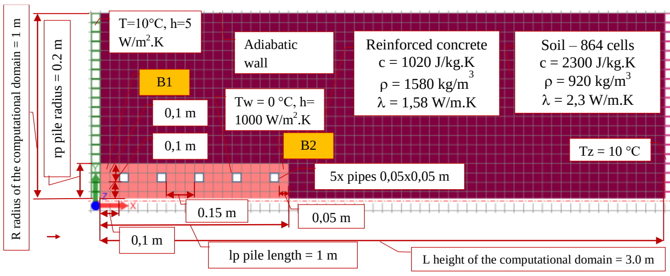


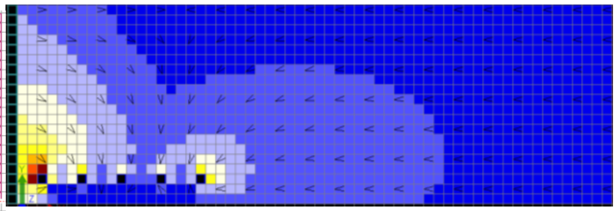
Verification case 3 – Definition and results

There is a good agreement between presented methods and Epilot software.

Verification case 4 – the non-stationary case by software CalA 2D - PL

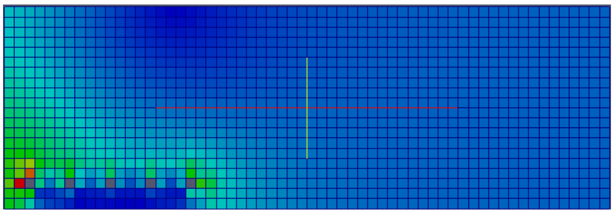
This is a transient verification on the case of 2D planar computational domain software in CalA.



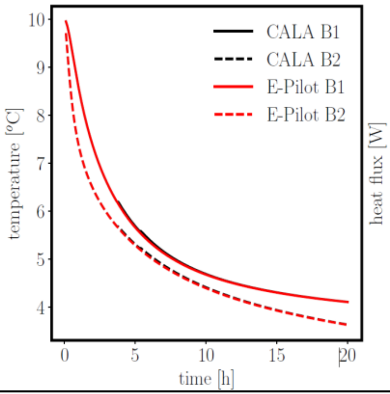


Example of heat flux field in time step 200 – CalA

Initial temperature = 10 ° C; Continued temperature = 0 ° C, h = 1000 W/m².K; Time step 360 s; Number of steps 200.



Example of heat flux field in time step 200 – Epilot

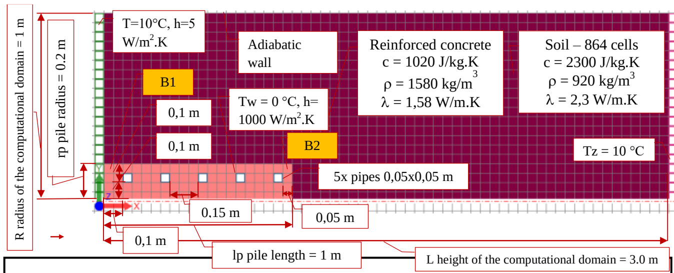


The course of temperatures in points B1 and B2

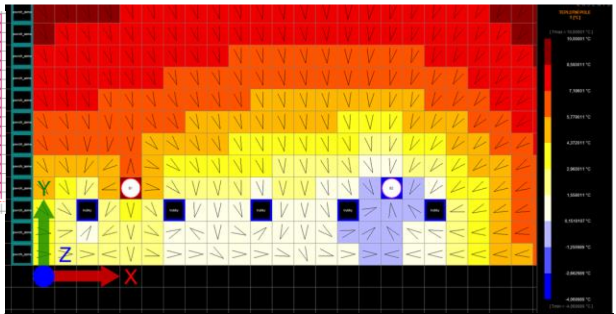
Verification case 4 – Definition and results

The agreement of the course of temperatures in the given points is good and the non-stationary solver is thus verified.

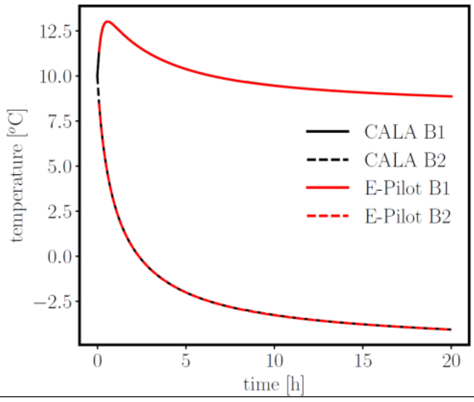
3.4 Verification case 5 – the non-stationary task with internal heat sources by software CalA 2D - PL



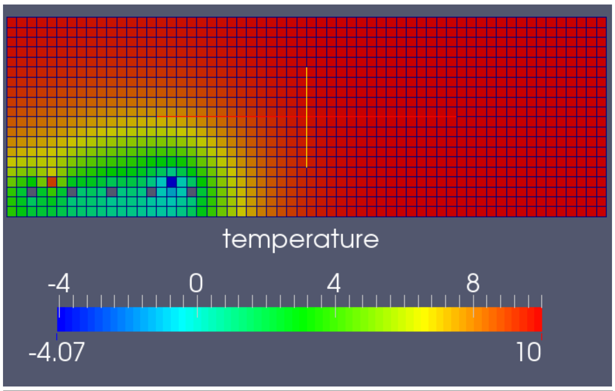
Initial temperature = 10 ° C; Continued temperature = 0 ° C, h = 1000 W/m².K; Time step 360 s; Number of steps 200; B1 - heat source +10,000 W/m²; B2 - heat drop with an output of -10,000 W/m²;



Example of heat flux field in time step 200 – CalA



The course of temperatures in points B1 and B2



Example of heat flux field in time step 200 – Epilot

Verification case 5 – Definition and results

The agreement of the course of temperatures in the given points is good and the non-stationary solver with internal heat sources is thus verified.

The aim of the paper was to describe the properties and possibilities of the newly developed software Epilot, designed to model the thermal behavior of thermally activated foundation structures – typically energy-piles. The performed verification tests prove the correctness of the used algorithms.

4 Acknowledgment

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