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A semi-analytical method and its application for calculating the thermal stress and displacement of sparsely fractured rocks with water flow and heat transfer

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METHOD

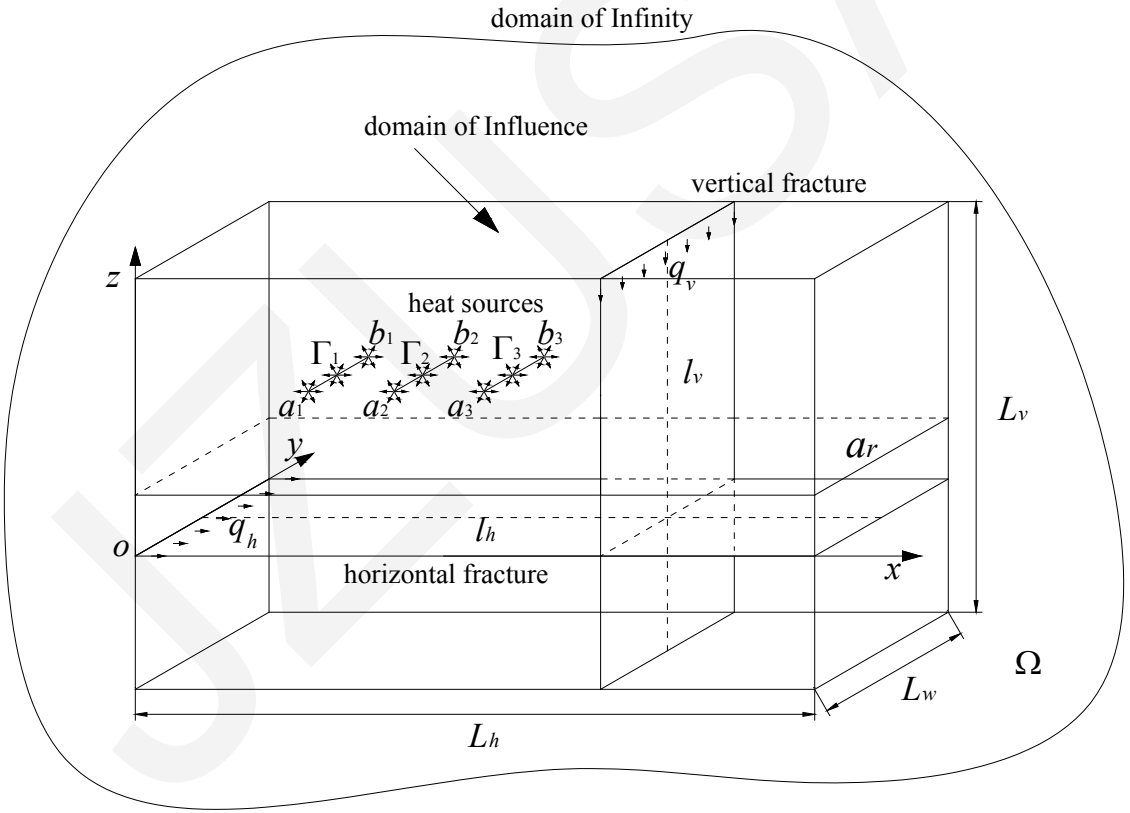
Processes of the semianalytical method

- Formulate an integral equation of the thermoelastic displacement potential in the Laplace-transformed domain.
- Discretize the fractures into rectangular elements.
- Calculate the elemental integrals that involve singularities analytically.
- Calculate the numerical solutions of the potential using numerical Laplace inversion.
- Calculate the temperature-gradient-induced displacements and stresses using central differences.

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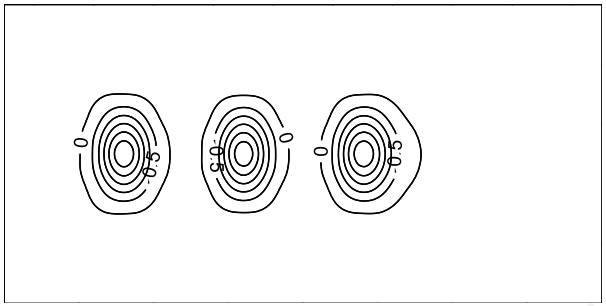
EXAMPLE MODEL

■ Heat transfer and thermal elastic model of a hypothetical radioactive waste repository

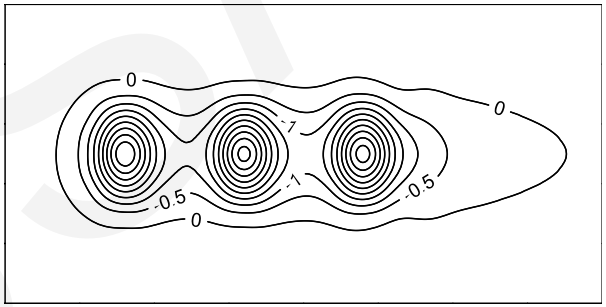


RESULT

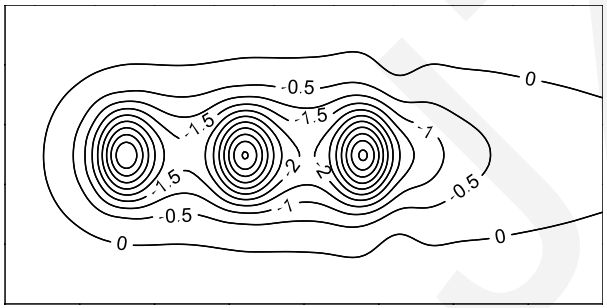
■Distributions of the temperature-gradient-induced stress σ_{zz}(MPa) of the rock matrix at the intersection with the horizontal fracture at selected times



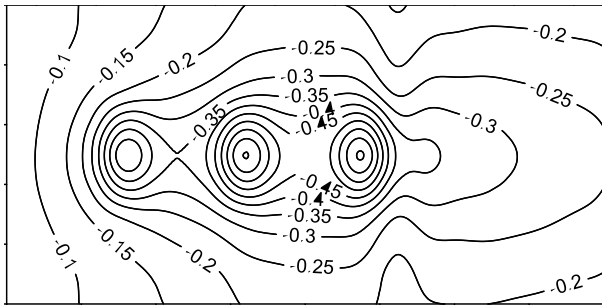
（a） t = 1 year



（b） t = 5 year



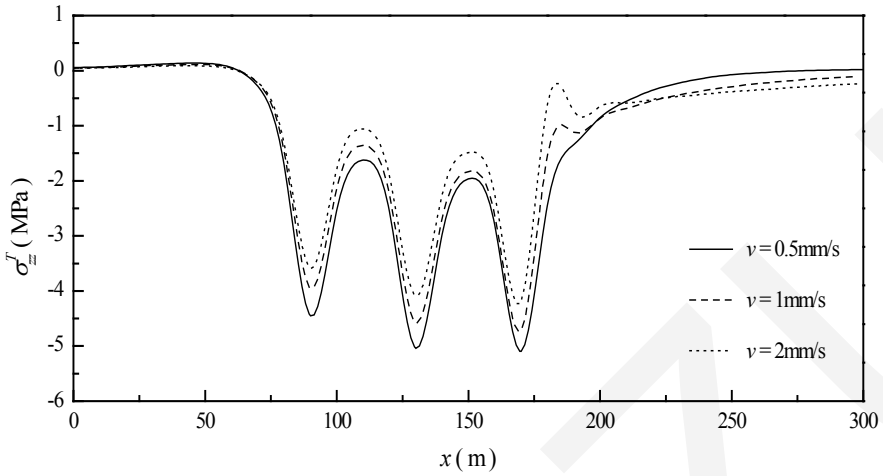
（c） t = 10 year



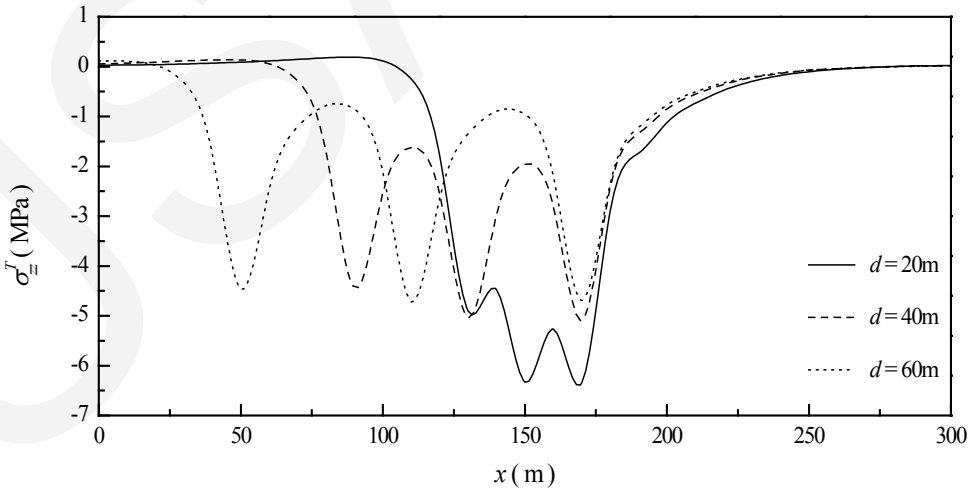
（d） t = 150 year

RESULT

■Effects of fracture water fluxes and spacing of heat sources



(a) *Distributions of stress σ_{zz}^T along the observation line l_h for selected water velocities*



(b) *Distributions of stress σ_{zz}^T along the observation line l_h for selected heat source locations*

CONLUSIONS

- In early time of operation of the repository, the region of rock under thermal expansion and compressive is limited.
- As the intensity of the heat source gets smaller with time, only a small portion of the rock expands whereas the remaining portion contracts.
- Downstream peak temperatures may be higher due to the supply of thermal energy by the water-flow-facilitated heat transfer, and patterns of influences of the water velocities on the thermal stress and displacement are similar.
- Sufficiently close heat sources would cause superposition of the heating effects and make the near-field temperature to increase significantly.

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