# A NEW NUMERICAL SIMULATION TECHNIQUE FOR EVALUATING FROST HEAVE BEHAVIOR UNDER A VARIETY OF HETEROGENEITY LEVELS OF FROZEN SOIL

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## Introduction

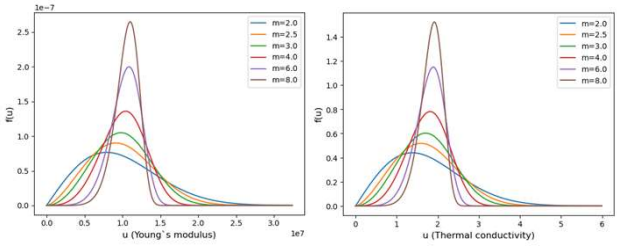
- The effect of heterogeneity of frozen soil on the soil freezing behavior has mostly been studied using a stochastic-conceptual approach (Amiri et al., 2018).
- Predicting frost heave behavior of heterogeneous soils is a complicated issue, it is necessary to establish a modeling scheme that can account for the effect of varied heterogeneity levels of frozen soil.

## Research aim

- This study established the finite element model with Abaqus considering the heterogeneity of frozen soil and modified the user subroutine code to apply a variety of heterogeneity levels.
- A newly established modeling technique enabled us to assess the effects of heterogeneity parameters of frozen soil on frost heave amount.

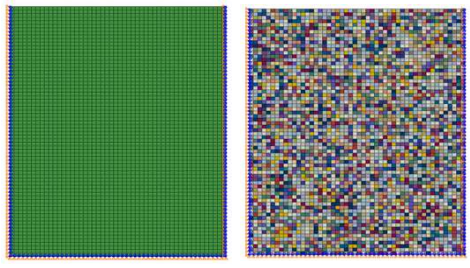
## Materials and methodology

- Thermo-mechanical coupled analysis was applied to simulate the frost heave behavior using the porosity rate function proposed by Michalowski and Zhu (2006). The implementation of the numerical model was performed using ABAQUS with User Subroutines such as UMATHT and UEXPAN.
- The heterogeneous 2D model was created in ABAQUS linked with Python Code, and the subroutine codes were modified and applied to be consistent with the heterogeneous model.




(a) Heterogeneity of E (b) Heterogeneity of $\lambda_p$

Fig. 1. Weibull distribution for material properties with different indices m



(a) Homogeneous model (b) Heterogeneous model

Fig. 2. Comparison between homogeneous and heterogeneous model

## Results and discussions

- As the heterogeneity of Young's modulus increased (as indices m decreased), the frost heave amount slightly increased, and the mean square error (MSE) for the experimental data also increased.
- On the other hand, high heterogeneity of particle thermal conductivity caused a sudden decrease of frost heave amount with a high increment of MSE.

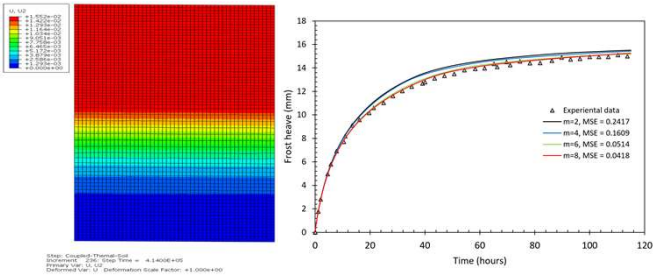



Fig. 3. Effect of heterogeneity of Young's modulus on frost heave amount

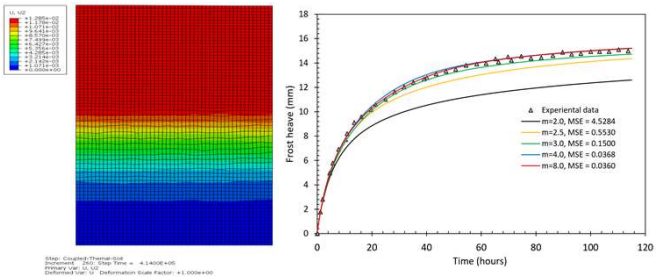



Fig. 4. Effect of heterogeneity of particle thermal conductivity on frost heave

## Conclusions

- The sensitivity of the heterogeneity to the amount of frost heave was greater for particle thermal conductivity than for Young's modulus.
- Through the new numerical simulation technique, the heterogeneity coefficient could be determined which makes predicted results to be consistent with experimental results.

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## References

1. Michalowski, R.L, and Zhu, M. (2006), "Frost heave modeling using porosity rate function", Int.J. Numer. Anal. Meth. Geomech., Vol.30, pp.709-722.
2. Amiri, E. A., Craig, J. R., and Kurylyk, B. L. (2018). A theoretical extension of the soil freezing curve paradigm. Advances in water resources, 111, 319-328.