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Large deformation analysis of slope failure using material point method with cross-correlated random fields

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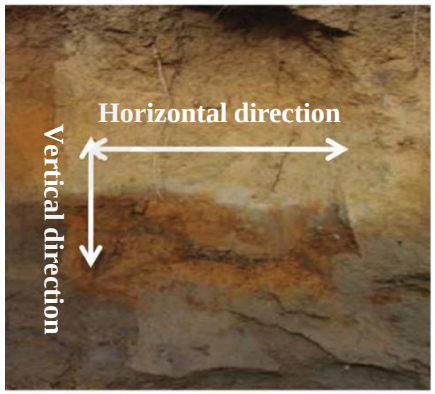
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Background: Slope failure & Spatial variability

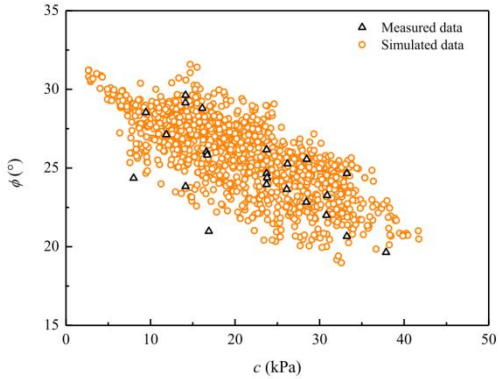




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H. Zhu, L. M. Zhang, Can Geotech J 50, 7 (2013).



M. X. Wang et al., Comput Geotech 118, (2020).

- Slope failure involves large deformation associated with tremendous damage to infrastructure and threatens the lives of people.

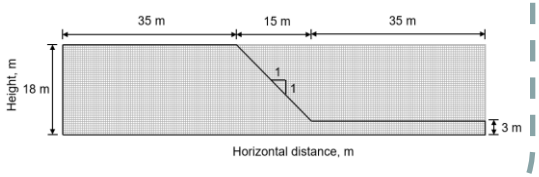
- Soil properties generally show spatial variability, and cohesion and friction angle are cross-correlated.

Methodology: Material Point method + Random field + Monte Carlo Simulation

Input

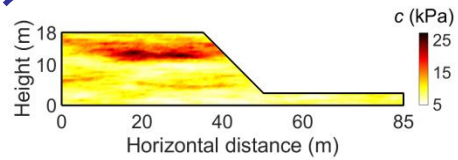


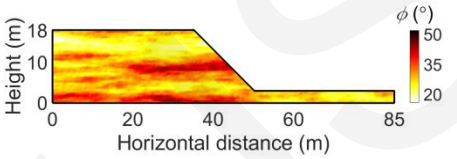
Soil information



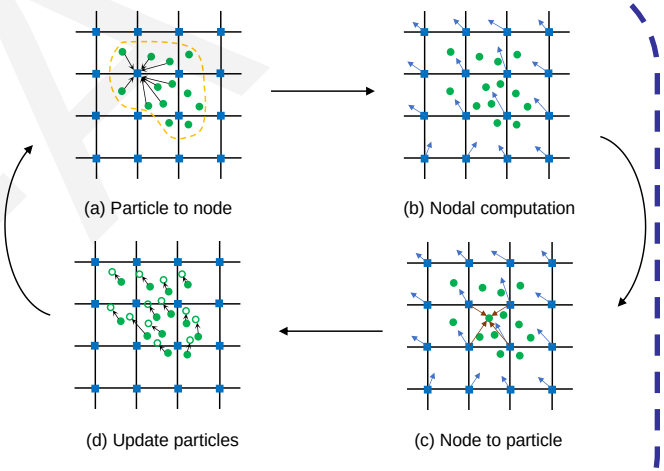
Slope model

Random material point simulation



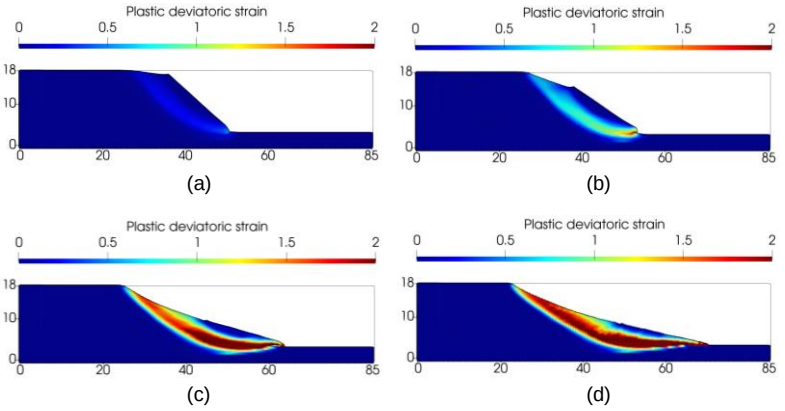


Random field generation

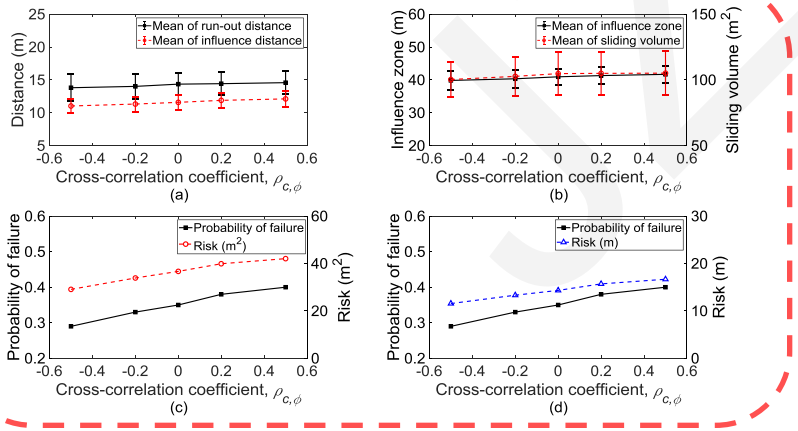


MPM calculation

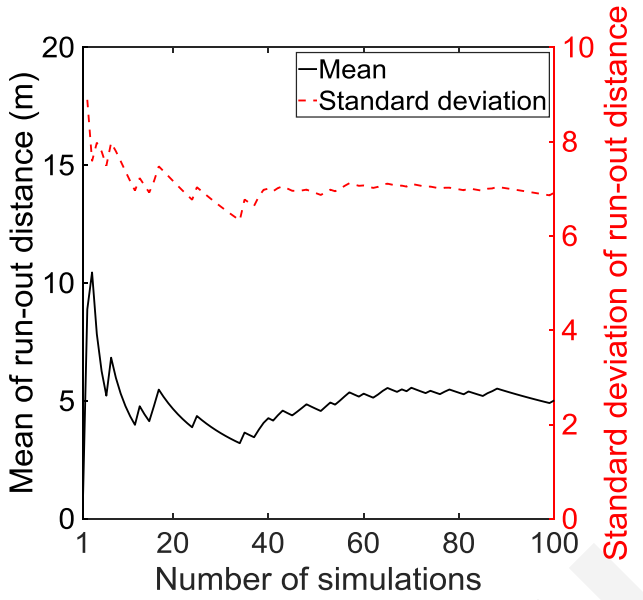
Post-failure behavior



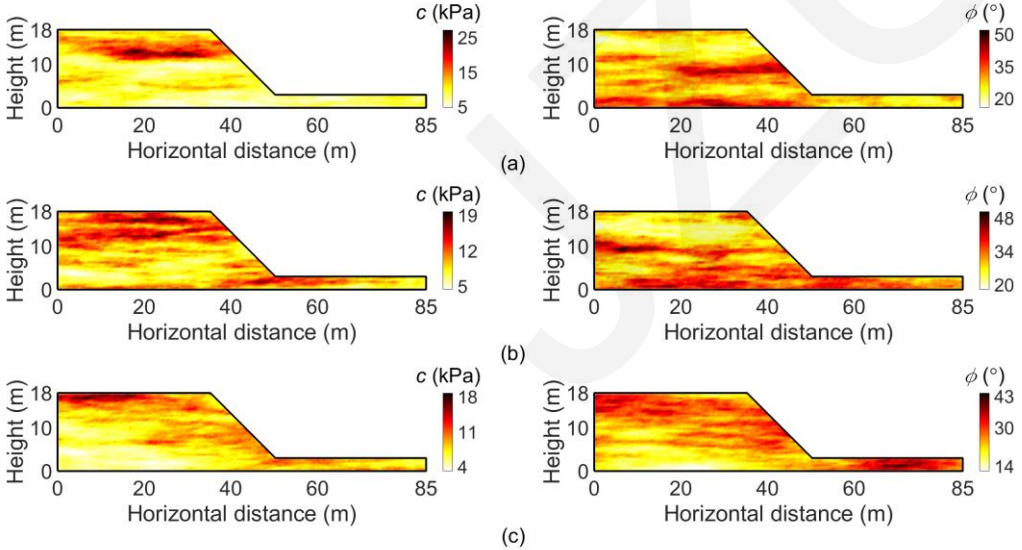
Risk assessment



Determination of the number of simulation runs

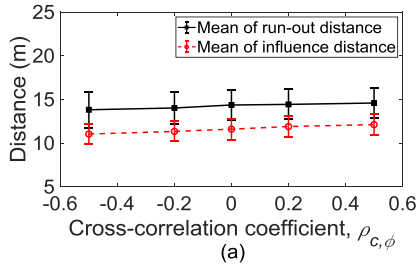


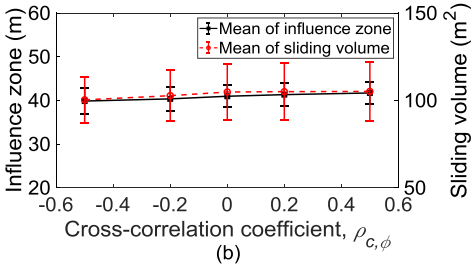
- According to convergence analysis, the number of Monte Carlo Simulation (MCS) realizations is set to 100.

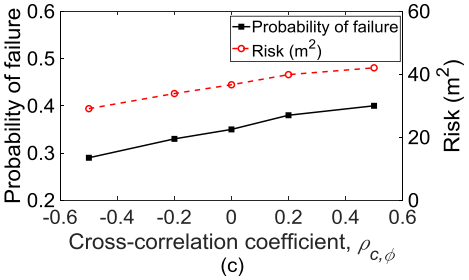


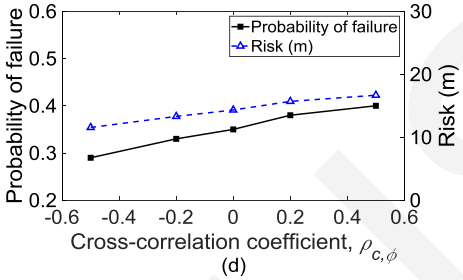
- Three examples of cross-correlated c-ϕ random fields: (a) $\rho_{c,\phi}$=-0.5 (negatively correlated); (b) $\rho_{c,\phi}$ =0.0 (independent); (c) $\rho_{c,\phi}$=0.5 (positively correlated).

Effects of $\rho_{c,\phi}$ on post-failure features and risks



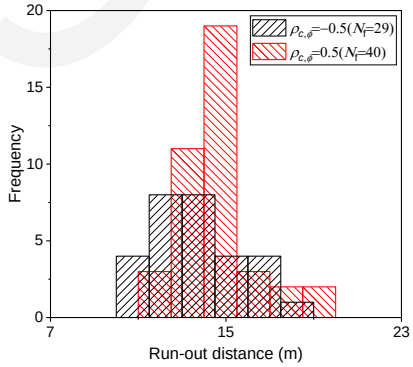


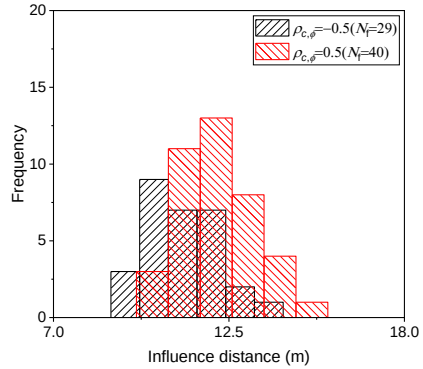


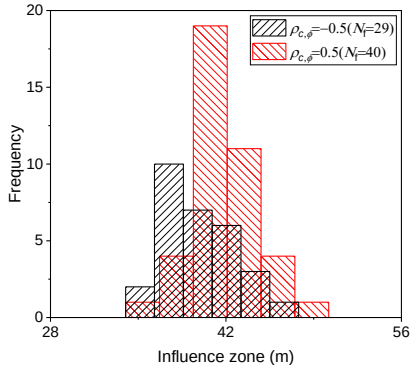


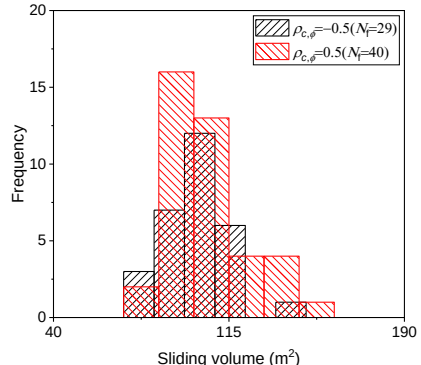
- When $\rho_{c,\phi}$ increases from −0.5 (the lowest risk) to 0.5 (the highest risk), the scattering of the influence zone and sliding volume of the slopes becomes larger.

- The mean values of slope post-failure consequences increase slightly with the increase of $\rho_{c,\phi}$, while the failure probability increases significantly with $\rho_{c,\phi}$.
- The risk indicators show a consistent trend with the probability of failure curve.

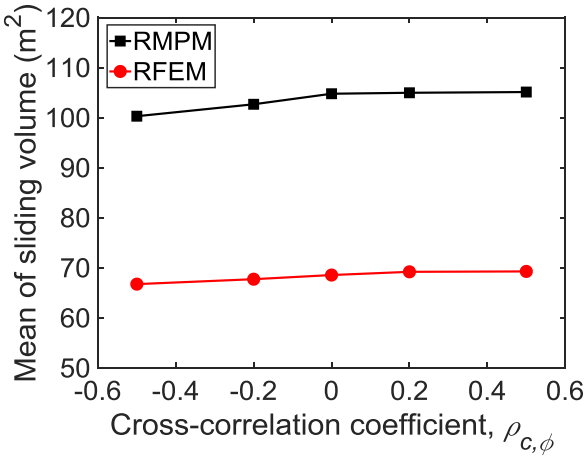


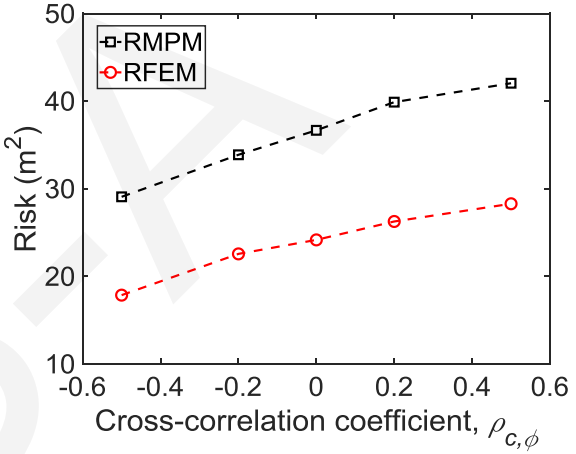


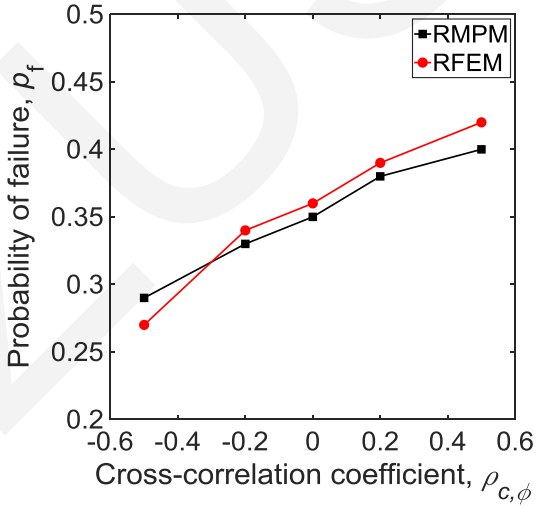




Random material point method vs. Random finite element method







- The probabilities of slope failure calculated by RFEM and RMPM under different cross-correlation coefficients were similar, while the calculated sliding volume and risk of failure by RFEM was considerably smaller than that by RMPM.

Conclusions

- RMPM simulation showed that the slope failure probability is greatly influenced by the cross-correlation coefficient of c and ϕ. A positive $\rho_{c,\phi}$ results in a larger failure probability than a negative cross-correlation. On the other hand, an increase in $\rho_{c,\phi}$ increases the post-failure consequences of the failed slopes only slightly (by 5~10%).

- The probabilities of slope failure calculated by RMPM and RFEM were quite similar, which indicates that both methods are capable of handling relatively small deformations upon triggering of a slope failure. However, RFEM considerably underestimates the post-failure features and risks associated with slope failure compared with RMPM, because FEM will end in non-convergence due to mesh distortion. The entire progressive slope failure process can be simulated using RMPM.

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