Investigation on pile behavior in proximity to excavation damage zone (EDZ) induced by TBM excavation

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Introduction

- Major urban areas requires underground space development.
- Conventional drill-and-blast tunneling method cannot be applied due to the excessive noise, vibration during excavation and especially its negative effect on nearby structures.
- However, the studies and investigations on mechanized or TBM tunnels are not as rigorous compared to the conventional methods.
- Although it is relatively difficult to gather field data during mechanized or TBM excavation process, the advancement of computational capacity large deformation problems such as tunnel excavation can be studied through numerical approach.

Excavation Damage Zone (EDZ)

✓ Excavation damage zones (EDZ) form during tunnel excavation process and cause deterioration to the surrounding ground and threatens the structural stability of the tunnel.

✓ The zones are designated based on the degree of damage (or the stress redistribution due to excavation) – excavation influence zone(EIZ), excavation damage zone(EDZ), highly damage zone(HDZ) and construction damage zone(CDZ).

✓ The EDZs cause structural stability issues on the excavation process as well as the tunnel structure.

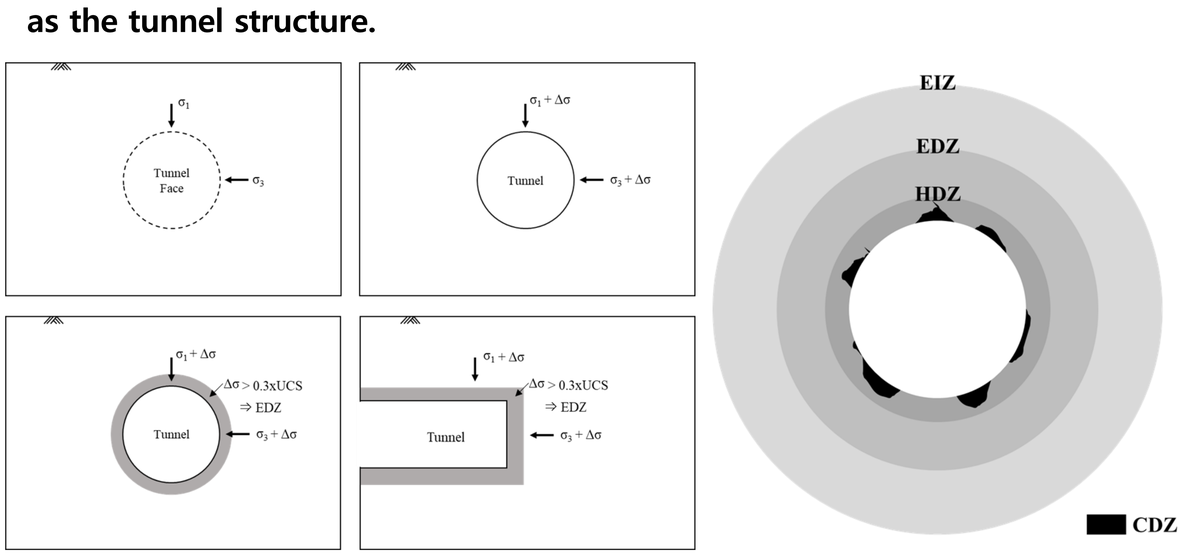
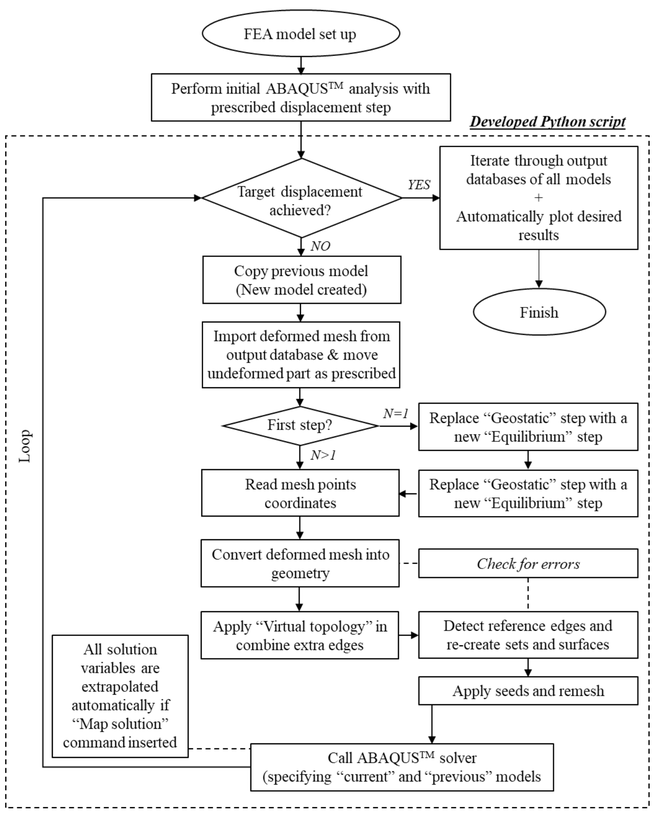


Fig. 1 Excavation damage zone and its distribution

Large deformation method – CEL and auto-remeshing

✓ Tunnel excavation process involves large deformation problems in which can't be dealt with conventional small deformation analysis methods
→ Application of large deformation method is necessary for proper study



✓ Auto-meshing after small strain method, which rearranges the mesh after designated step to prevent excessive mesh distortion and error.

✓ Additional large deformation method, the coupled Eulerian-Lagrangian method was applied to verify the outcome of the numerical analysis.

✓ The flow chart of the PYTHON modelling of the auto-remeshing method is shown on the left side.

Numerical modelling

✓ The auto-remeshing process is modelled to remesh after every 0.1cm – the excavation will be carried out for 30cm (300 steps). After 300 steps, the stress redistribution was found to converge.

✓ The cutterhead was modelled to rotate and advance in a constant rate.

✓ The modelling of the different degree of EDZs were designated based on the stress redistribution associated with the original rock mass' uniaxial compression strength,
- HDZ: 50% of rock mass UCS
- EDZ: 30% of rock mass UCS
- EIZ: 15% of rock mass UCS

the CDZ was not considered in the analysis since the size was negligible.

✓ The tip of the pile was placed within the respective EDZs, above and on the side.

✓ The behavior of the pile was investigate based on the difference in settlement and the lateral movement during the TBM excavation simulation.

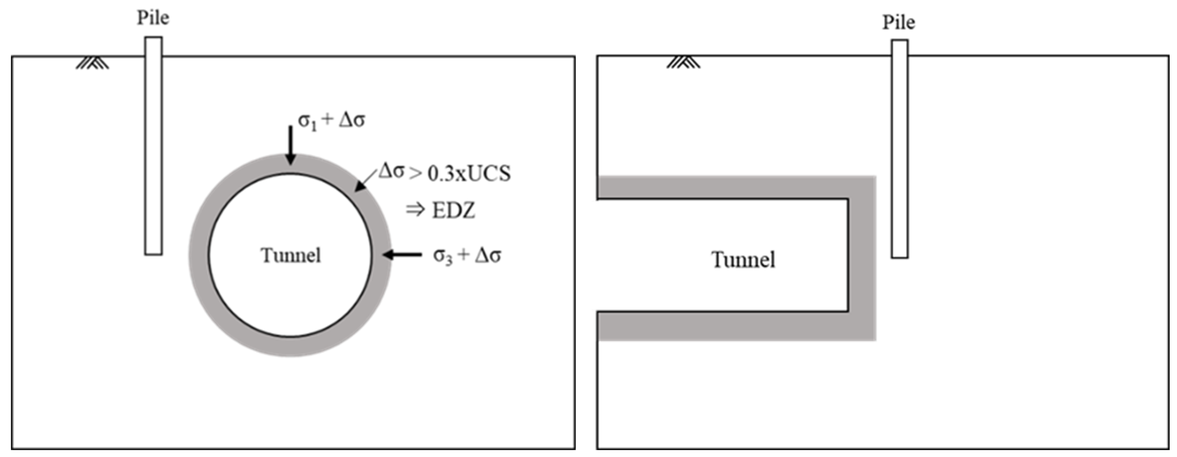


Fig. 2 Numerical modelling of piles near TBM excavation

Numerical results and conclusions

✓ The effect of the TBM excavation simulated based on auto-remeshing and CEL method showed similar results – yielding a constant tendencies and size of the EDZs forming around the surrounding grounds → Can assume the numerical model used in this study is capable of simulating and predicting the TBM excavation and its effects.

✓ It was obvious that the bigger the damage due to excavation, it caused bigger changes in pile behavior.

✓ The behavior of the piles in the EDZs were…
- HDZ: 41% increase in settlement, 0.18D lateral movement towards TBM
- EDZ: 22% increase in settlement, 0.10D lateral movement towards TBM
- EIZ: 3% increase in settlement, 0.02D lateral movement towards TBM

✓ Although numerous studies reported that the EIZ does not undergo any changes in mechanical properties, it was shown to have a minor effect on the pile behavior.

✓ Additional numerical cases, after the TBM excavation (where there were no further excavation process simulated) was conducted to see the permanent effect on the EDZs.

✓ The behavior of the piles in the EDZs with no additional TBM simulation…
- HDZ: 31% increase in settlement, 0.07D lateral movement towards TBM
- EDZ: 14% increase in settlement, 0.033D lateral movement towards TBM
- EIZ: no increase in settlement, no lateral movement towards TBM

✓ This can be the indication of the HDZ and EDZ having an irreversible effect on the rock mass, while the damage in EIZ can be reversible.