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Energy evolution and blast response of segmented circular tunnels; Considering depth and different soils

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ABSTRACT

Energy assessment of deep tunnels depends on the depth and what kind of ground they surrounded by .The numerical results showed that high static compressive stress concentration around the underground tunnel results in the accumulation of substantial strain energy at the same location. The roof and floor of the tunnel are more prone to dynamic failures during the blasting loading process. In addition, the analysis of energy dissipation indicated that the strain energy reduction and the residual kinetic energy are positively related to the lateral pressure coefficient and the burial depth of the tunnel, and the residual kinetic energy is much larger than the strain energy reduction under the same condition. Furthermore, for an underground tunnel subjected to high in situ stress, the blasting stress wave with lower amplitude is sufficient to trigger severe dynamic failures. Results indicate that a tunnel in saturated soil is more vulnerable to severe damage than that buried in either partially saturated soil or dry soil. The tunnel is also more vulnerable to surface explosions that occur directly above the centre of the tunnel than those that occur at any equivalent distance in the ground away from the tunnel centre.
Keywords: Dynamic stress concentration, Energy evolution, Blasting load, Numerical simulation, *soil*

1. INTRODUCTION

In recent years, the exhaustion of mineral resources in shallow depths, and the rapid development of tunneling and hydropower engineering, have considerably motivated the tunnel excavations to extend to depth. However, due to the complicated geological environment in which deep excavations are carried out, a large number of unconventional rock failure phenomena such as spalling,[1], [2] zonal disintegration phenomenon [3], [4] and rock burst hazards [5],[6] have been observed during underground excavations. These accidents or hazards will bring about damages to equipment and delays of excavation operation, and even pose great threats to the safety of construction personnel. Therefore, it is an urgent issue to figure out the mechanism of the engineering disasters occurring in deep excavations. In practice, underground rocks and ores are naturally stressed by gravitational and tectonic stress. When an underground tunnel is excavated, the previous stress states existing in rock mass are disturbed, with the radial principal stress being released and tangential principal stress concentrating in the periphery of the tunnel.[7][8][9] in this process, the strain energy releases at some locations while accumulating at other locations, which leads to different mechanical responses of underground tunnels under dynamic disturbance.[10][11] In addition, during the underground excavation process, the excavation damaged zone (EDZ) is formed in the proximity of the excavated tunnel. To date, considerable research efforts were devoted to investigating the formation of EDZ and the fracture mechanisms of surrounding rock during underground excavations. [12][13][14][15][16][17] For instance, a series of studies have been carried out at the Underground Research Laboratory (URL) since 1983 to study excavation responses when underground openings were excavated.[13][14] Findings of these works showed that various factors such as the nearfield stress history, geological variability, excavation method, tunnel geometry, and confining pressure are responsible for the excavation damage and instability of underground openings. The presence of the EDZ around an underground opening in turn has a great influence on the mechanical, hydraulic, and thermal characteristics of surrounding rock masses. However, previous research works on the instability of underground openings focus on static and quasi-static conditions, and few reports have considered the effect of dynamic disturbance. Many evidences showed that, during underground excavations, dynamic disturbance such as explosion-induced vibrations from adjacent tunnel and stress impact from neighboring rock bursts have a significant influence on existing tunnels.[18][19][20] Therefore, the dynamic disturbance is an important factor to be considered when studying the stability of deep-buried tunnel.
The drill and blast (D&B) method is extensively used in mining and tunneling engineering, because it is still an economical and efficient excavation approach for rock fracture and fragmentation.[21] When the drill and blast method