ABSTRACT

Tunnelling is essential for underground mining. It can also facilitate sufficient underground spaces to accommodate public utilities and infrastructures, which are required for the urbanization over the time. When a tunnel is forwarded through soil or rock, support pressure is required to be provided in the form of lining or anchorage system to prevent the active collapse of the surrounding soil/rock and the opening. Tunnelling through soil and rock may encounter various challenges. Inflow of groundwater towards the openings during tunnelling through rocks and soils below groundwater table is one of such major challenges. In such case seepage forces are generated around the tunnel and can impart instability to the underground excavations and tunnels. With the development in tunnelling technologies and advanced equipment for ground excavation, the non-circular tunnels like elliptical or rectangular shaped tunnels have become popular over the decades. These tunnels provide maximum functional space compared to circular tunnels. The present research studies the stability of elliptical and semi-elliptical tunnels in anisotropic cohesive and cohesionless soils, rectangular tunnel in dry cohesionless soil, submerged cohesionless soil and Hoek-Brown rock masses located below the groundwater table. Lower bound limit analysis in conjunction with finite elements and various optimization techniques have been employed to study the stability of tunnel in soil and rock for different ground conditions. Mohr-Coulomb yield criterion is used to model cohesive-frictional and cohesionless soils whereas Tresca yield criterion is used for saturated clay in undrained condition. Hoek-Brown yield criterion is used to model the rock mass. The total head distribution in the soil and rock domains for tunnel located below the groundwater table has been obtained by carrying out finite element analysis using OPTUM G2. The seepage analysis has been performed assuming a steady-state groundwater flow towards the tunnel. The study shows that the stability of tunnels in soil increases with decrease in shear strength parameters. The increase in the normalized rate of undrained shear strength of clay can cause an increase in the stability of tunnel. The increase in shear strength anisotropy in undrained cohesive soil and in dry/drained cohesionless soil decreases the stability of tunnel. The effect of increase in seepage anisotropy is found to be significant at higher cover depth ratio of soil for fully submerged soil. The increase in (i) depth of tunnel roof/crown from ground surface, (ii) height of groundwater table and (iii) aspect ratio of tunnel decreases the stability of tunnel embedded in both soil and rock. Increase in degree of disturbance (*D*) and decrease in geological strength index (GSI) of rock mass can significantly decrease the stability of tunnel. The effect of both increase in *D* and GSI on the stability of tunnel is higher for rock mass with higher normalized uniaxial compressive strength. Design equations are proposed to determine the normalized support pressure required for tunnel to resist the active collapse by conducting regression analysis.

Keywords: Tunnelling, non-circular tunnel, stability, limit analysis, optimization, soil, rock, seepage, shear strength anisotropy, seepage anisotropy.