ABSTRAK

ANALISIS ELASTO PLASTIK BUKAAN SILINDRIS BERBASIS HOEK-BROWN PADA TEROWONGAN KALILINGSENG

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Kestabilan terowongan pada massa batuan heterogen memerlukan pendekatan yang mampu menggambarkan perilaku elasto-plastik secara realistis. Penelitian ini menganalisis respons elasto-plastik Terowongan Kalilingseng (Kulon Progo) menggunakan kriteria Hoek-Brown (H-B) dan formulasi analitik Carranza-Torres & Fairhurst (CTF) untuk bukaan silindris. Parameter massa batuan diturunkan dari klasifikasi lapangan (GSI = 50) dan back-analysis RocLab, menghasilkan mb = 1.509, s = 0.003866, a = 0.5057, Erm = 1.76 GPa, dan v = 0.28. Tegangan in-situ pada kedalaman 34 m menghasilkan σv = 0.637 MPa, σh = 0.322 MPa, dan tegangan tereskala S_0 = 0.0252. Hasil menunjukkan tekanan dinding kritis awal plastis P_{i*} = 0.00213; radius zona plastis relatif ξ = 1.010 (≈1% di luar dinding) dan penutupan dinding tak berdimensi Ur = 0.000487 yang setara dengan defleksi aktual ur = 0.73 mm untuk radius b = 1.5 m. Profil tegangan di dinding memberikan $\sigma r(b)$ = 0.0017 MPa dan $\sigma\theta(b)$ = 0.958 MPa, masih jauh di bawah kekuatan massa batuan. Kurva respons tanah (GRC) menunjukkan tren menurun non-linier tanpa lonjakan deformasi, konsisten dengan rezim mild yielding pada diagram nondimensi Carranza-Torres & Fairhurst. Hasil ini menegaskan bahwa massa batuan berada pada keadaan stabil alami, dan strategi penyangga yang diperlukan cukup bersifat kontrol deformasi.

Kata kunci: elasto-plastik, Ground Reaction Curve, GSI, Hoek-Brown, kestabilan terowongan

ABSTRACT

ELASTO-PLASTIC ANALYSIS OF A CYLINDRICAL OPENING BASED ON THE HOEK-BROWN CRITERION IN THE KALILINGSENG TUNNEL

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Tunnel stability in heterogeneous rock masses requires an approach capable of realistically describing elasto-plastic behavior. This study analyzes the elasto-plastic response of the Kalilingseng Tunnel (Kulon Progo) using the Hoek–Brown (H–B) failure criterion and the analytical formulation of Carranza-Torres & Fairhurst (CTF) for cylindrical openings. Rock mass parameters were derived from field classification (GSI = 50) and RocLab back-analysis, resulting in mb = 1.509, s = 0.003866, a = 0.5057, Erm = 1.76 GPa, and v = 0.28. In-situ stresses at a depth of 34 m yielded σv = 0.637 MPa, σh = 0.322 MPa, and scaled far-field stress S_0 = 0.0252. The results indicate a critical internal pressure for initial yielding of P_{i*} = 0.00213; a relative plastic zone radius ξ = 1.010 (≈1% beyond the tunnel wall); and a dimensionless wall convergence Ur = 0.000487, equivalent to an actual radial displacement of ur = 0.73 mm for a tunnel radius b = 1.5 m. The stress profile at the tunnel boundary shows σr(b) = 0.0017 MPa and σθ(b) = 0.958 MPa, both significantly lower than the rock mass strength. The Ground Reaction Curve (GRC) exhibits a smooth nonlinear decreasing trend without abrupt deformation jumps, consistent with a mild yielding regime in the Carranza-Torres & Fairhurst nondimensional framework. These findings confirm that the rock mass is in a naturally stable condition, and any required support system would primarily function as deformation control.

Keywords: elasto-plastic, Ground Reaction Curve, GSI, Hoek–Brown, tunnel stability.