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Influencing Factors on Stability of Shale with Silt Layers at Slopes

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Abstract : Shale rockmasses often include silt layers, impacting slope stability in construction and mining. Analyzing their interaction is crucial for long-term stability. A study used an elastoplastic model, incorporating the stress transfer method and Coulomb's criterion, to assess a shale rock mass with silt layers. It computed stress distribution, assessed failure potential, and identified vulnerable regions where nodal forces were calculated for a comprehensive analysis. A shale rock mass ranging from 14.75 to 16.75 meters thick, with silt layers varying from 0.36 to 0.5 meters, was considered in the model. It examined four silt layer conditions: horizontal (SiHL), vertical (SiVL), inclined against slope (SiIincAGS), and along slope (SilincALO). Mechanical parameters like uniaxial compressive strength (UCS), tensile strength (TS), Young's modulus (E), Poisson's ratio, and density were adjusted for varied scenarios: UCS (0.5 to 5 MPa), TS (0.1 to 1 MPa), and E (6 to 60 MPa). In elastic analysis of shale rock masses, stress distributions vary based on layer properties. When shale and silt layers have the same elasticity modulus (E), stress concentrates at corners. If the silt layer has a lower E than shale, marginal changes in maximum stress (σmax) occur for SilHL. A decrease in σmax is evident at SilVL. Slight variations in σmax are observed for SilincAGS and SilincALO. In the elastoplastic analysis, the overall decrease of 20%, 40%, 60%, 80%, and 90% was considered. For SilHL:(i) Same E, UCS, and TS for silt layer and shale, UCS/TS ratio 5: strength decrease led to shear (S), tension then shear (T then S) failure; noticeable failure at 60% decrease, significant at 80%, collapse at 90%. (ii) Lower E for silt layer, same strength as shale: No significant differences. (iii) Lower E and UCS, silt layer strength 1/10: No significant differences. For SilVL: (i) Same E, UCS, and TS for silt layer and shale, UCS/TS ratio 5: Similar effects as SilHL. (ii) Lower E for silt layer, same strength as shale: Slip occurred. (iii) Lower E and UCS, silt layer strength 1/10: Bitension failure also observed with larger slip. For SilincAGS: (i) Same E, UCS, and TS for silt layer and shale, UCS/TS ratio 5: Effects similar to SilHL. (ii) Lower E for silt layer, same strength as shale: Slip occurred. (iii) Lower E and UCS, silt layer strength 1/10: Tension failure also observed with larger slip. For SilincALO: (i) Same E, UCS, and TS for silt layer and shale, UCS/TS ratio 5: Similar to SilHL with tension failure. (ii) Lower E for silt layer, same strength as shale: No significant differences; failure diverged. (iii) Lower E and UCS, silt layer strength 1/10: Bitension failure also observed with larger slip; failure diverged. Toppling failure was observed for lower E cases of SilVL and SilincAGS. The presence of silt interlayers in shale greatly impacts slope stability. Designing slopes requires careful consideration of both the silt and shale's mechanical properties. The temporal degradation of strength in these layers is a major concern. Thus, slope design must comprehensively analyze the immediate and long-term mechanical behavior of interlayer silt and shale to effectively mitigate instability.

Keywords : shale rock masses, silt layers, slope stability, elasto-plastic model, temporal degradation
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