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PENGARUH KONDISI TANAH TAK JENUH TERHADAP KESTABILAN LERENG REKLAMASI TAMBANG TERBUKA
Muhammad Fatih Husaen, Dr.Eng. Ir. Sito Ismanti, S.T., M.Eng., IPM
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INTISARI

Kegiatan penambangan nikel laterit dengan metode tambang terbuka menyisakan lereng reklamasi yang disusun dari hamparan material *overburden* dan *top soil* tanpa pemadatan mekanis, sehingga berporositas tinggi dan rentan terhadap infiltrasi air hujan. Pendekatan analisis kestabilan konvensional yang mengasumsikan kondisi jenuh sempurna dinilai kurang representatif, sebab zona di atas muka air tanah berada dalam kondisi tak jenuh, di mana kuat geser dikontrol oleh tegangan isapan matriks (*matric suction*) yang berkurang secara transien seiring meresapnya air hujan. Penelitian ini bertujuan menentukan karakteristik retensi air material timbunan melalui Kurva Karakteristik Air-Tanah (*SWCC*), menganalisis pengaruh infiltrasi terhadap tekanan air pori dan rembesan transien, serta mengevaluasi penurunan faktor keamanan (FK) lereng berbasis fungsi waktu.

Penelitian dilaksanakan pada lereng reklamasi Bukit Terra, Kabupaten Kolaka, Sulawesi Tenggara. Karakteristik retensi air diperoleh melalui pengujian kertas saring (ASTM D5298, Whatman No. 42), dicocokkan dengan model Fredlund-Xing (1994). Data curah hujan 30 tahun diuji konsistensinya dengan RAPS, lalu dianalisis untuk hujan rencana kala ulang 2, 5, 10, dan 20 tahun yang dipecah menjadi hujan jam-jaman (metode Mononobe) dengan variasi waktu puncak. Rembesan transien dimodelkan dengan SEEP/W (steady-state, *prewetting*, pembebanan hujan) dan kestabilan dianalisis dengan SLOPE/W metode Morgenstern-Price selama 24 jam pada tiga geometri lereng.

Material timbunan menunjukkan AEV rendah (1,6–2,4) dan kadar air volumetrik jenuh mencapai 38–53%, dengan R^2 = 0,98–0,99. Intensitas puncak hujan seluruh kala ulang (52–82 mm/jam) melampaui kapasitas infiltrasi material (≈54 mm/jam), sehingga sebagian curah hujan menjadi limpasan. Akibatnya, pola hujan seragam meskipun intensitasnya terendah menghasilkan infiltrasi efektif terbesar dan menjadi kondisi paling kritis, dengan FK minimum 1,669 (Lereng 2, T20). Seluruh FK tetap di atas batas aman (1,1). Disimpulkan bahwa analisis tanah tak jenuh memberikan gambaran penurunan FK lebih realistis, dan pengendali utama kestabilan adalah kapasitas infiltrasi material, bukan intensitas hujan semata.

Kata kunci: reklamasi tambang, tanah tak jenuh, kurva karakteristik air-tanah (*SWCC*), rembesan transien, faktor keamanan

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ABSTRACT

Open-pit nickel laterite mining leaves behind reclamation slopes formed from loosely placed *overburden* and *top soil* without mechanical compaction, resulting in high porosity and susceptibility to rainfall infiltration. Conventional stability analysis that assumes fully saturated conditions is considered less representative, since the zone above the groundwater table is in fact unsaturated, where shear strength is governed by matric *suction* that decreases *transient*ly as rainwater infiltrates. This study aims to determine the water-retention characteristics of the fill material through the Soil-Water Characteristic Curve (*SWCC*), to analyze the effect of rainfall infiltration on pore-water pressure and *transient* seepage, and to evaluate the time-dependent reduction of the slope Factor of Safety (FoS).

The study was conducted on the reclamation slope of Bukit Terra, Kolaka Regency, Southeast Sulawesi. Water-retention characteristics were obtained through the filter paper method (ASTM D5298, Whatman No. 42) and fitted using the Fredlund-Xing (1994) model. Thirty years of rainfall data were tested for consistency using the RAPS method, then analyzed to obtain design rainfall for 2-, 5-, 10-, and 20-year return periods, distributed into hourly rainfall using the Mononobe method with varying peak times. *Transient* seepage was modeled in SEEP/W (steady-state, *prewetting*, and rainfall loading), and stability was analyzed in SLOPE/W using the Morgenstern-Price method over 24 hours for three slope geometries.

The fill material exhibited a low *Air-entry value* (1.6–2.4 kPa) and a saturated volumetric water content of 38–53%, with R^2 = 0.98–0.99. The peak rainfall intensity of all return periods (52–82 mm/hour) exceeded the material's infiltration capacity (≈54 mm/hour), causing part of the rainfall to become runoff. Consequently, the uniform rainfall pattern (despite its lowest intensity) produced the largest effective infiltration and became the most critical condition, with a minimum FoS of 1.669 (Slope 2, T20). All FoS values remained above the safety threshold (1,1). It is concluded that unsaturated analysis provides a more realistic depiction of FoS reduction, and that slope stability is governed primarily by the material's infiltration capacity rather than by rainfall intensity alone.

Keywords: mine reclamation; unsaturated soil; soil-water characteristic curve (*SWCC*); *transient* seepage; factor of safety