INTISARI

Pembangunan Bendungan Bulango Ulu dilatarbelakangi permasalahan banjir dan kebutuhan air baku di wilayah Kabupaten Bone Bolango dan perkotaan Gorontalo. Bendungan direncanakan memiliki terowongan pelimpah dengan total panjang 352.46 m. Dalam penyusunan desain terowongan pelimpah belum spesifik menjelaskan kondisi geologi teknik sepanjang terowongan pelimpah. Pemetaan geologi dilakukan pada lokasi bendungan dan sekitar area genangan dengan struktur geologi utama adalah sesar normal dan sesar mendatar. Penentuan kualitas massa batuan pada terowongan pelimpah sudah dilakukan berdasarkan klasifikasi *Central Research Institute of Electric Power Industry* (CRIEPI) dan *Rock Mass Rating* (RMR) tetapi belum dilakukan secara detail. Namun, dengan tingginya ketidakpastian pada kondisi geologi bawah permukaan, maka diperlukan analisis kualitas massa batuan dengan pendekatan metode lain. Ketidakstabilan lereng terjadi menyebabkan runtuhnya lereng portal outlet terowongan pelimpah. Perkuatan lereng dilakukan dengan *grouting* konsolidasi perlu dilakukan penyelidikan awal untuk mengetahui pengaruh *grouting* terhadap kestabilan lereng portal. Penelitian ini bertujuan untuk menentukan kondisi geologi teknik, penentuan metode penggalian dan sistem penyangga terowongan, dan penyelidikan awal efektivitas *grouting* terhadap kestabilan lereng. Pada penelitian ini dilakukan pemetaan geologi dan geologi teknik, analisis kualitas massa batuan dengan GSI, RMR, dan *Q-System*, analisis penyelidikan awal efektivitas *grouting*, dan analisis pengaruh *grouting* terhadap kestabilan lereng. Hasil penelitian menunjukkan bahwa lokasi penelitian tersusun atas tiga satuan batuan yaitu satuan andesit, diorit, dan endapan pasir-berangkal. Struktur geologi yang teridentifikasi adalah sesar dan kekar. Kualitas massa batuan pada bukaan terowongan berdasarkan RMR terdiri dari diorit kualitas *very poor* (*section* 1 dan 3) dan diorit kualitas *fair* (*section* 2), berdasarkan *Q-System* terdiri dari diorit kualitas *extremely poor* (*section* 1 dan 3) dan diorit kualitas *fair* (*section* 2). Metode penggalian pada *section* 1 dan 3 berdasarkan GSI dan RMR yaitu *digging* dengan metode *multiple drifts* laju penggalian 0.5 - 1.5 m dan pada *section* 2 dilakukan dengan *blasting* metode *top heading* dan *bench* laju penggalian 1.5-3 m. Sistem penyangga berdasarkan RMR pada *section* 1 dan 3 menggunakan baut batuan diameter 20 mm, panjang 5-6 m, spasi 1-1,5 m dengan *wire mesh* pada atap dan dinding, *shotcrete* tebal 15-20 cm (atap), 15 cm (dinding), dan 5 cm (muka galian), dan *steel sheet* spasi 0.75 m dengan *forepoling*, pada *section* 2 dengan baut batuan diameter 20 mm, panjang 4 m, spasi 1.5-2 m dengan *wire mesh* pada atap, *shotcrete* tebal 5-10 cm (atap) dan 3 cm (dinding). Sistem penyangga berdasarkan *Q-System* pada *section* 1 dan 3 menggunakan baut batuan diameter 20 mm, panjang 3 m, spasi 1-1,2 m, *sprayed concrete fibre reinforced* (SFR) tebal 15-25 cm, *steel ribs* tipe RRS II (D45/6+2 dia. 16-20 mm), tebal *ribs* 45 cm, spasi *ribs* 2.3 m dengan *forepoling*. Hasil parameter kuat geser *grouting* umur 7 hari setelah injeksi diperoleh nilai kohesi tidak mengalami perubahan sebesar 0,181 kg/cm^2, sedangkan peningkatan sudut geser dalam tidak signifikan dari 15,79^o menjadi 20,45^o (meningkat 29.5%). Hasil analisis stabilitas lereng setelah *grouting* (umur 7 hari) dengan metode LEM diperoleh nilai faktor keamanan lereng (Fs) = 0,656 $\leq$ 1, menunjukkan efek *grouting* pada umur 7 hari dengan peningkatan pada sudut geser dalam tidak berpengaruh besar terhadap kestabilan lereng.

Kata kunci: Terowongan, kualitas massa batuan, metode penggalian, sistem penyangga, *grouting*, LEM, kestabilan lereng

ABSTRACT

The development of the Bulango Ulu Dam was motivated by flooding problems and the need for raw water in the Bone Bolango Regency and Gorontalo urban areas. The dam is designed to have a spillway tunnel with a total length of 352.46 m. In the preparation of the spillway tunnel design, it is not yet specific to explain the engineering geological conditions along the spillway tunnel. Geological mapping was carried out at the location of the dam and around the inundation area with the main geological structures being normal faults and strike-slip faults. Determination of rock mass quality in spillway tunnels has been carried out based on the classification of the Central Research Institute of Electric Power Industry (CRIEPI) and Rock Mass Rating (RMR) but has not been carried out in detail. However, with high uncertainty in subsurface geological conditions, it is necessary to analyze the rock mass quality with another method approach. Slope instability occurs causing the outlet of the spillway tunnel portal slope to collapse. Slope reinforcement is carried out by consolidation grouting, it is necessary to conduct a preliminary investigation to determine the effect of grouting on the stability of the portal slope. This research aims to determine engineering geological conditions, determine excavation methods and tunnel support systems, and preliminary investigations of the effectiveness of grouting on slope stability. In this research, geological and engineering geology mapping, rock mass quality analysis using GSI, RMR, and Q-System, preliminary investigation analysis of the effectiveness of grouting, and analysis of the effect of grouting on slope stability was carried out. The results showed that the research location was composed of three rock units, namely andesite, diorite, and alluvial deposits. The identified geological structures are faults and joints. The rock mass quality in the tunnel opening based on RMR consists of very poor quality diorite (sections 1 and 3) and fair quality diorite (section 2), while based on the Q-System it consists of extremely poor quality diorite (sections 1 and 3) and fair quality diorite. (section 2). Excavation methods in sections 1 and 3 are based on GSI and RMR, namely digging with multiple drifts method with excavation rate of 0.5 - 1.5 m and in section 2 carried out by blasting with top heading and bench method with excavation rate of 1.5-3 m. The support system based on RMR in sections 1 and 3 uses rock bolts with a diameter of 20 mm, length of 5-6 m, spacing of 1-1.5 m with wire mesh on the roof and walls, shotcrete 15-20 cm thick (roof), 15 cm (wall), and 5 cm (excavation face), and steel sheet spaced 0.75 m with forepoling, in section 2 with rock bolts 20 mm in diameter, 4 m long, 1.5-2 m spaced with wire mesh on the roof, shotcrete 5-10 thick cm (roof) and 3 cm (wall). The support system based on Q-System in sections 1 and 3 uses rock bolts with a diameter of 20 mm, length of 3 m, spacing of 1-1,2 m, sprayed concrete fiber reinforced (SFR) 15-25 cm thick, steel ribs type RRS II (D45/6+2 dia. 16-20 mm), ribs thickness of 45 cm, rib spacing of 2.3 m with forepoling. The results of the grouting shear strength parameter at 7 days after injection obtained that the cohesion value did not change at 0.181 kg/cm^2, while the increase in the internal friction angle was not significant from 15.79^o to 20.45^o (an increase of 29.5%). The results of the analysis of slope stability after grouting (age 7 days) using the LEM method obtained the value of the slope safety factor (Fs) = 0.656 $\leq$ 1, indicating that the effect of grouting at the age of 7 days with an increase of internal friction angle did not have a major effect on slope stability.

Keywords: Tunnel, rock mass quality, excavation method, support system, grouting, LEM, slope stability