RINGKASAN

RANCANG BANGUN SISTEM MONITORING PERGESERAN TANAH DENGAN MEMANFAATKAN DIGITAL CALIPER DAN SENSOR KELEMBABAN TANAH PADA SIMULASI MODEL LERENG BUATAN

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Tanah longsor merupakan bencana geologi yang sering terjadi di Indonesia dan menimbulkan kerugian besar, mulai dari kerusakan infrastruktur hingga korban jiwa. Infiltrasi air hujan meningkatkan kadar air dalam tanah dan menurunkan kekuatan gesernya, sehingga kestabilan lereng mudah terganggu. Untuk mendukung upaya mitigasi, diperlukan sistem monitoring pergeseran tanah yang sederhana, akurat, dan dapat diimplementasikan pada skala laboratorium maupun lapangan. Penelitian ini mengembangkan prototipe instrumen monitoring berbasis digital caliper yang dimodifikasi sebagai linear encoder guna mengukur displacement translasi, serta sensor kelembaban tanah resistif untuk memantau dinamika kadar air akibat infiltrasi. Sistem terdiri dari dua unit, yaitu alat utama dan pasak sensor, yang diintegrasikan menggunakan protocol MQTT menggunakan mikrokontroler ESP8266 dan ESP32 C3. System utama dilengkapi modul RTC, OLED, SD card, dan sistem pasak dilengkapi sensor MPU6050 untuk memantau orientasi pasak. Pengujian dilakukan pada model lereng buatan skala laboratorium dengan dua kelas kemiringan (24° dan 35°) pada kondisi tanah kering serta hujan buatan. Data displacement, kelembaban, dan orientasi pasak direkam secara real-time untuk menganalisis respons tanah selama proses pergeseran.

Hasil penelitian menunjukkan bahwa prototipe bekerja konsisten dan stabil pada seluruh skenario uji. Digital caliper menghasilkan error rata-rata 3,42% (akurasi 96,58%), sementara sensor kelembaban tanah memiliki error rata-rata 3,23% (akurasi 96,77%). Pengujian hujan buatan menunjukkan bahwa pergerakan tanah mulai meningkat signifikan pada kelembaban kritis 37-40%. Orientasi pasak pada sumbu (pitch dan roll) berada pada rentang (0°-6°), sehingga pergerakan yang terjadi dapat dipastikan berupa translasi tanpa rotasi signifikan. Drift pada sumbu yaw muncul akibat akumulasi error gyroscope tanpa referensi magnetometer. Secara keseluruhan, prototipe terbukti mampu memantau displacement, kelembaban, dan orientasi secara reliabel, sehingga efektif digunakan sebagai instrumen deteksi awal potensi pergerakan tanah pada skala laboratorium.

Kata kunci : tanah longsor, longsoran translasi, *linear encoder, digital caliper,* sensor kelembaban tanah

SUMMARY

DESIGN AND DEVELOPMENT OF A SOIL DISPLACEMENT MONITORING SYSTEM UTILIZING A DIGITAL CALIPER AND SOIL MOISTURE SENSOR ON A SIMULATED SLOPE MODEL

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Landslides are a geological disaster that frequently occur in Indonesia and cause substantial losses, ranging from infrastructure damage to loss of life. Rainwater infiltration increases the water content in the soil and reduces its shear strength, making slope stability more susceptible to disturbance. To support mitigation efforts, a simple, accurate, and field-deployable monitoring system is required, suitable for both laboratory and real-world conditions. This study develops a prototype monitoring instrument utilizing a modified digital caliper as a linear encoder to measure translational displacement, along with a resistive soil moisture sensor to monitor water-content dynamics induced by infiltration. The system consists of two units the main device and the sensor stake integrated via the MQTT protocol using ESP8266 and ESP32-C3 microcontrollers. The main unit is equipped with an RTC module, OLED display, and SD card, while the stake unit includes an MPU6050 sensor to monitor its orientation. Experiments were conducted on a laboratory-scale artificial slope model with two slope classes (24° and 35°) under dry conditions and simulated rainfall. Displacement, moisture content, and stake orientation data were recorded in real time to analyze soil responses during the movement process.

The results indicate that the prototype operated consistently and stably across all test scenarios. The digital caliper produced an average error of 3.42% (accuracy of 96.58%), while the soil moisture sensor showed an average error of 3.23% (accuracy of 96.77%). The artificial rainfall test revealed that soil movement began to increase significantly at a critical moisture level of 37-40%. The stake orientation along the pitch and roll axes remained within the range of 0°-6°, confirming that the observed movement was translational with no significant rotation. Drift in the yaw axis occurred due to gyroscope error accumulation in the absence of a magnetometer reference. Overall, the prototype successfully monitored displacement, moisture, and orientation with high reliability, demonstrating its effectiveness as an early-warning instrument for potential soil movement at laboratory scale.

Keywords : *landslide, translational landslide, linear encoder, digital caliper, soil moisture sensor*