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Geotechnical Data Analysis Contributing Rainfall Triggering Landslide Risk Assessment at Kawkhali Upazila of Rangamati District, Bangladesh

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Abstract: On 13 June 2017, a catastrophic landslide struck the south-eastern Tertiary hilly region of Bangladesh, marking one of the deadliest disasters in the country's history. At least 165 people, including children and four army personnel, lost their lives in multiple slope failures across Rangamati, Bandarban, and Chittagong districts. Detailed field investigations were conducted in Kawkhali Upazila of Rangamati district, where original slope angles were measured at affected sites. Soil samples were collected for laboratory analyses at the Engineering Geological Laboratory of the Geological Survey of Bangladesh, following relevant ASTM standards. Particle size distribution was determined using sieve and hydrometer analyses, while shear strength parameters were obtained through direct shear tests under consolidated drained conditions, ASTM D 3080. Sieve analysis revealed that sand content ranged from 95.84 to 99.51 percent, with silt and clay comprising 0.49 to 4.13 percent. The uniformity coefficient varied between 2.79 and 6.5, and the coefficient of curvature ranged from 0.55 to 1.96. Hydrometer results indicated variable proportions of sand, silt, and clay, leading to classification as silty sand, sandy silt, and clayey silt. The average liquid limit was 34.94 percent, indicating moderate plasticity and potential deformation. Cohesion values ranged from 2.41 to 15.56 kPa, and internal friction angles from 26.75° to 35.40°. High sand content, low cohesion, and steep slope angles collectively contributed to slope instability and failure.

Keywords: ***Kawkhali Upazila, Landslide, Geotechnical parameters, Shear strength, Particle size, Slope angle*.**

Introduction

Landslides are a natural disaster in the mountainous region of southeastern Bangladesh. Landslides caused by heavy rains often result in loss of life and casualties. On 13 June 2017, a large-scale landslide hit the southeastern Tertiary mountainous region of the country, surpassing all previous disaster records in Bangladesh. At least 165 people, including children and four army personnel, were killed in different landslides caused by landslides in different parts of the Rangamati, Bandarban, and Chattogram districts. In July 2017, 21 people lost their lives due to landslides in Betbunia, Fatikchari, Ghagra, and Kalampati Union of Kawkhali Upazila. In this context, GSB's Environmental Geology and Natural Hazard Assessment branch have decided on the annual outdoor program in the said Kawkhali Upazila in the fiscal year 2021-2022.

Location, extent, and accessibility

Kawkhali Upazila under Rangamati District in the Chattogram Division of Bangladesh located between 22°29' to 22°44'N latitude and 91°56' to 92°80'E longitude (Figure 1). The area is bounded by Naniarchar and Loxmichari Upazila of Rangamati to the north, Rangunia and Raozan of Chattogram district to the south, Rangamati Sadar and Kaptai Upazila of Rangamati to the east and Fatikchari and Raozan Upazila of Chattogram to the west. The study area encompasses 04 Union i.e., Ghagra, Fatikchari, Kalampati and Betbunia with the total surface area of approximately 339.29 km^2.

Structure and tectonics

The folds of the CTFB comprise the youngest structural subdivision of the western flank of the Indo-Burma Ranges (Hossain et al., 2014). The geological studies completed in this western collapsed flank area show that the CTFB has not been grown simultaneously; rather, this fold-thrust belt has grown dynamically toward the west (Hossain et al., 2018). The deformation force of the belt changes from west to east.

In the western part of the CTFB, a significant number of folds have been dynamic just from the Late Pliocene or even later (Khan et al., 2018). The CTFB has created linear NNW-SSE to N-S to NNE-SSW oriented doubly plunging folds, which are lined up with the general pattern of the IBR. In view of the shape and folding intensity, Bakhtine (1966) separated the CTFB into three divisions. From east to west, these are eastern highly compacted disturbed zone, center asymmetric thrust faulted zone, and western quite zone.

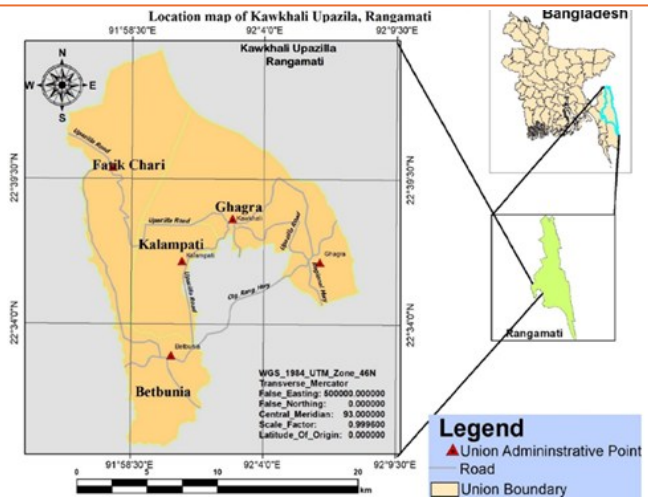

Figure 1, Locations of the study area. (Source: LGED, 2025).

Methodology

At the beginning of the program, all the baseline studies including the identification of landslide-prone areas with the help of Landsat, Sentinel, and Google Earth images are done. The topographical map of the said Upazila is prepared by analyzing the Sentinel image before the outdoor survey and then every aspect is confirmed in the field survey. Through surface inspection the size, shape, and mass movement of landslides are determined, and samples are collected for analyzing geo-engineering properties. In addition, necessary information is collected through focus group discussions (FGD) among concerned institutions and landslide-prone areas. GIS software was used for different map preparation and analysis. Geographic Information System (GIS), as a computer-based system for data capture, input, manipulation, transformation, visualization, combination, query, analysis, modeling, and output, with its excellent spatial data processing capacity, has attracted great attention in natural disaster assessment (Carrara et al., 1999). Different thematic maps were prepared from different satellite images and validated by checking the landslide point data collected from the field. A landslide hazard zoning map is prepared by applying the Knowledge-based rating and weighting method in GIS.

Geotechnical data analysis

Atterberg limit test, hydrometer test, grain size distribution, sieve analysis and direct shear test was executed at the Engineering Geological laboratory of GSB. From the test results obtained from sieve analysis shows that the amount of sand in the sample is 95.84 - 99.51% whereas total amount of silt and clay is 0.49 - 4.13%. From the hydrometer analysis result it is seen that sand particles vary from 0.44 to 58%, silt particles vary from 29.52- 75.10%, and clay particles varies from 4.5- 42.5%. Samples can be categorized as 5 samples are silty sand, 6 samples are sandy silt, and 6 samples are clayey silt depending on the particle sizes present in soil. Average Liquid limit of the review region is 34.9412%, demonstrating the high expansion potential of the soil. In this condition the deformation of the slope is possible and ultimately resulting in the slope being in an unsteady condition. As per the field perception, the original slope and angle of the landslide locales is similarly high, and it differs from 24° to 84° and around 40% of sites have slope angle more than 45°. Results from the direct shear test show that cohesion of sediment taken from landslide destinations is exceptionally low. It changes from 2.41 to 15.56 kPa. This is because of the high level of sand size particles and the nonappearance of conspicuous sand and clay proportions. In addition, internal friction angle estimated at eight distinct landslide destinations shifts from 25.70° to 35.40°.

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