A Slope Monitoring Test using Ground-Based SAR Technique

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Abstract : The Ku-band ground-based synthetic aperture radar (GBSAR) and micro-movement imaging technologies(MMI) were conducted in this research. Field observations were performed at Wufeng Elementary School in Wufeng Township, Hsinchu County, for monitoring of sub-millimeter displacement by conducting scans with a 5-minute interval on Jun. 2, Jul. 14, and Aug.18, respectively. Meanwhile, a time-series analysis was performed in a real-time manner, and tunable radar reflectors were applied to validate the accuracy of micro-displacement (2 to 3mm) measurement through on-site observations.

The GBSAR equipment, when properly configured, can be applied for landslide disaster warnings in various applications, including open pit mine, volcanic activities, retaining walls, and snow avalanche areas, etc. This study aims to reduce the risk of potential slope failure and to ensure safety.

Keywords : *GBSAR, micro displacement, slope monitoring, open pit mine monitoring*

1.Introductions

Small surface movements may be precursors of slope failures. Based on SAR interferometry technique, GBSAR system is able to remotely measure the displacement of thousands of points on the slope without the need for access to the target under observation. The proposed G2000M system can provide displacement maps to clearly distinguish between stable and moving portions of the slope. Meanwhile, time-series displacement can be measured for each point with an accuracy of up to 0.5 mm. The automatic acquisition and processing of GBSAR data enables the device to provide early warning alerts if movements exceed a selected threshold.

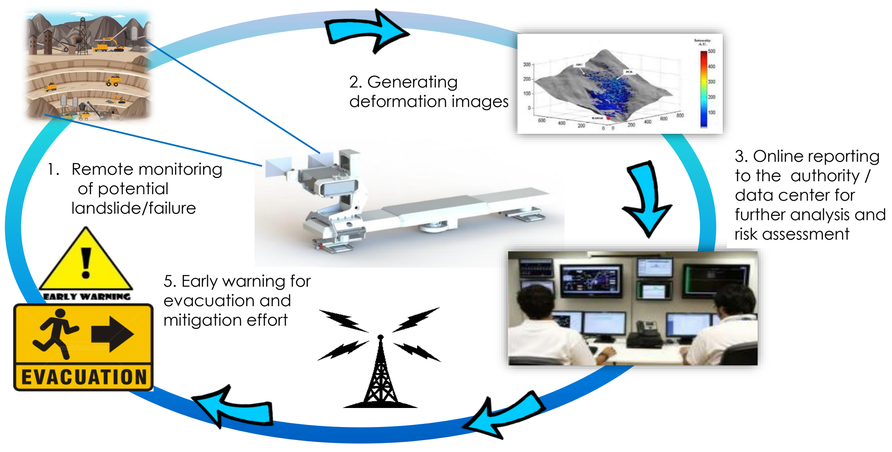

Fig.1 Workflow for preventive monitoring of geologic hazard and man-made structure

2.Research Area

The G2000M monitoring session was carried out in collaboration with Wufeng elementary school to evaluate the stability of a slope inside the play ground. According to the GPS observation data at the leveling point G416 (Wufeng Elementary School), the site experienced land subsidence by about 2.1 cm between 2013 and 2014 [Ref.1]. However, the velocity pattern is inconsistent with that of the neighboring areas. It remains unclear whether the displacement is related to regional slope movement, such that further observation and analysis are required to account for the deformation scenario.

Fig.2 Study area- Wufon Elementary School

Fig.3 Deformation of play ground stairs

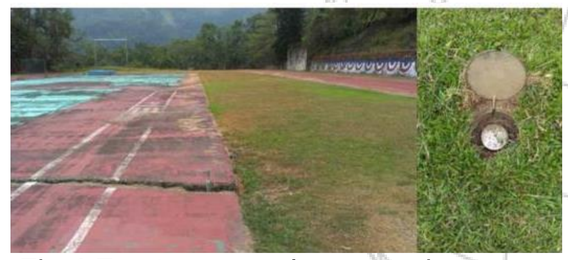

Fig.4 Fractures on play ground runways and leveling point G416

3.GBSAR and System Settings

G2000M Main Features

- ◆Remote sensing device with range distance up to 2 km
- ◆High accuracy: up to 0.5 mm (Line of sight)
- ◆Real-time monitoring on wide coverage
- ◆Sampling for point movement every 5 min
- ◆Autonomous operation system
- ◆Operates in all weather conditions
- ◆Easy to deploy and remote control capability

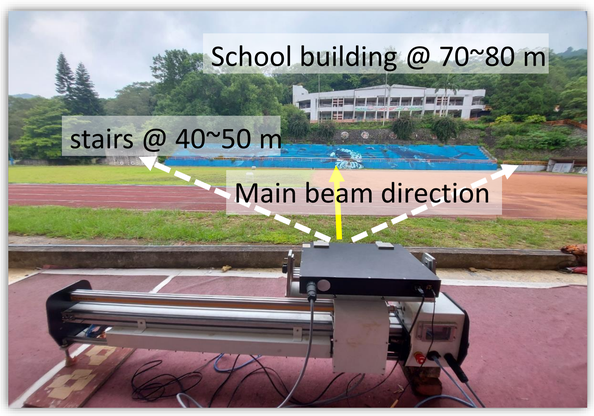

Fig.5 GBSAR setup on ceremonial stand

4.Results and Discussions

GBSAR system was deployed on the ceremonial stand and monitored the play ground and school facilities with main beam direction set at 255°. The software of G2000M (MMI) creates the amplitude, coherence, phase and displacement map for duration of 2~4 hours on each days. Fortunately, there is no critical change in the region after a thorough monitoring of this area during the observation days.

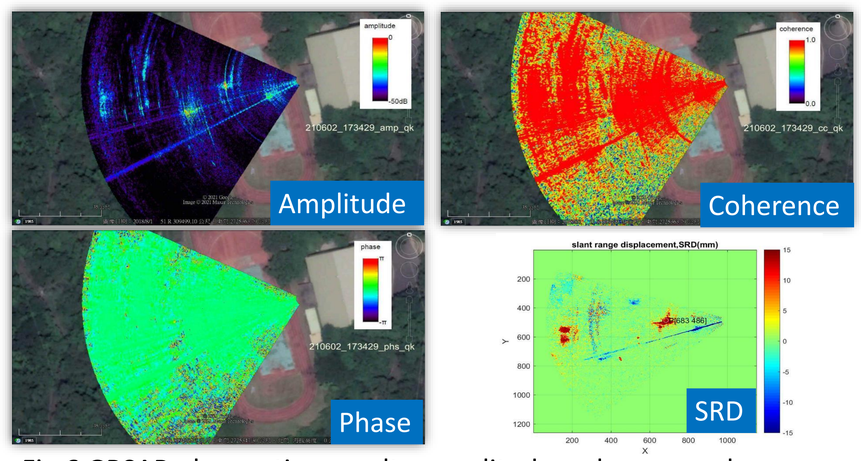

Fig.6 GBSAR observation results- amplitude, coherence, phase, and slant range displacement(SRD) maps

5.Validations

To validate the capability of GBSAR for detection of millimeter-level movement, we specifically deployed a tunable trihedral which can adjust the range distance between the target reflector (trihedral) and sensor (GBSAR). By comparing the man-made movement and observation results, it indicated that G2000M system can correctly detect the L.O.S displacement and observation results were synchronized with the trihedral settings.

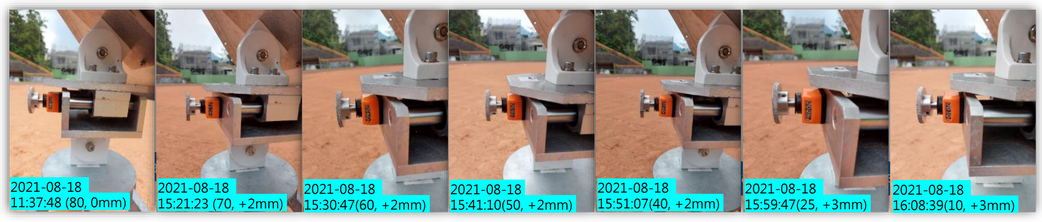

Fig.7 Settings of tunable trihedral

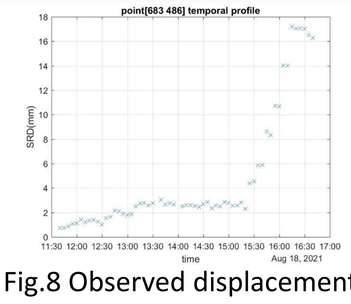

Fig.8 Observed displacements coincided with trihedral settings

6.Monitoring of Open Pit Mine Slope (1/2)

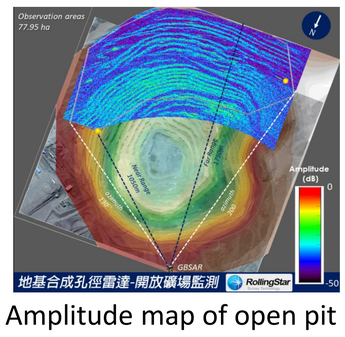

Fig.9 Amplitude map of open pit mine

Slope failures in large surface mines represent a major challenge for the safety of mine operators. The proposed GBSAR system (G2000M) has been deployed in an open pit mine for operational monitoring of potential slope failure.

7.Monitoring of Open Pit Mine Slope (2/2)

The cumulative displacement maps in open pit mine below clearly identified a moving portion of the central lower part of the slope right above the location of the excavator. Movement is clearly coherent in the area, showing a gradual increase in pixel velocity moving away from the most unstable part of the area. Early detection of slope movements has successfully allowed mine authority to implement appropriate actions and to minimize the threats of slope failure on personnel safety.

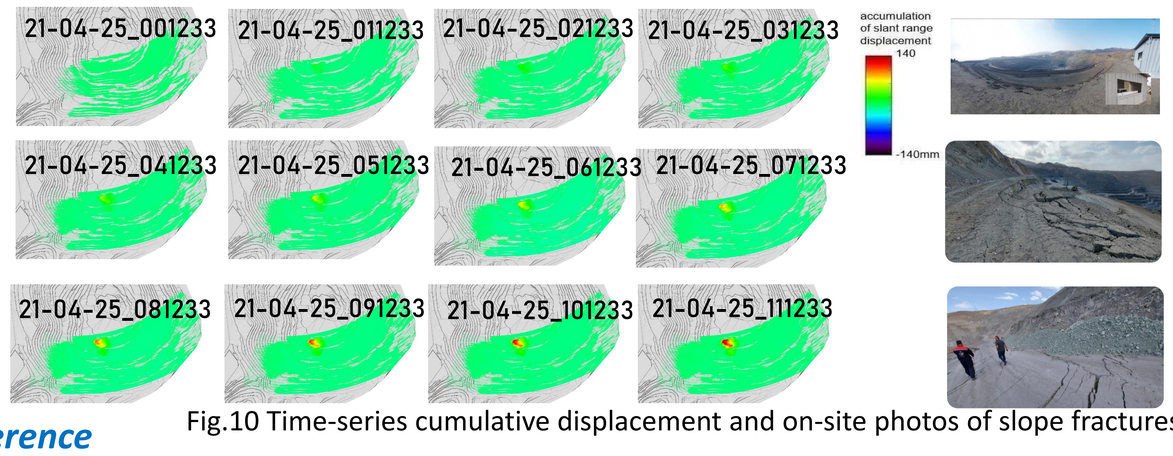

Fig.10 Time-series cumulative displacement and on-site photos of slope fractures

8.Reference

1. CGS, 2018; Central Geological Survey of the Ministry of Economic Affairs, 2018 Annual Committee Plan Final Report (No.107-5226904000-07-01), Taiwan

9.Acknowledgement

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