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自動化土石流觀測系統之發展及應用

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摘　　要　本文介紹行政院農業委員會水土保持局自 2002 年起於全台各地建置的 13 處自動化土石流觀測站，其目的為蒐集本土化之現場土石流觀測資訊，掌握土石流的發生及動態，瞭解土石流運動過程中各項行為機制，做為未來設計各項土石流防治措施及學術研究的參考。自動化土石流觀測系統主要可分為現場觀測儀器、前端儀器屋、中端傳輸模組及後端展示模組四大部分，各觀測站現有之觀測儀器包括雨量計、CCD 攝影機（含投射燈）、鋼索檢知器、地聲檢知器及超音波水位計等。系統平時以低負載的正常模式（normal mode）運作，當其所在地區的降雨超過預先設定的基準時，系統將自行提昇成事件模式（event mode），在事件模式時所有觀測儀器開始運作，系統自動蒐集並記錄現地觀測資料後再透過傳輸模組傳回水土保持局土石流防災應變系統（http://fema.swcb.gov.tw），即時提供決策參考以擬定有效的應變措施，而相關人員亦可透過遠端搖控模組控制土石流觀測站部分儀器並強制提升其運作模式。此外，系統設計為半開放式之共用平台，未來可提供其它不同觀測儀器進行現地研究測試與資料蒐集，達到資源整合的目的。系統建置完成後，位於南投縣信義鄉神木村的土石流觀測站於 2004 年 7 月 2 日敏督利颱風侵台期間蒐集到台灣地區第一筆現場土石流觀測資料，由資料中得知土石流發生前河道流量明顯變小，土石流波湧表面呈現波浪狀並有巨礫集中前端的現象，而土石流波前通過後其流深迅速變小，前端觀測流速介於 10—13 m/sec，前端流深約 5.5—6 m，最大觀測粒徑約 4—5m，平均流深約 2m，持續時間達 5 分鐘之久。本文另以快速傅立葉轉換（FFT）分析土石流流動造成的地表震動訊號（亦稱土石流地聲），發現土石流地聲頻率介於 2—150 Hz，尤其集中在 5—60 Hz 之間，其顯著頻率（superior frequency）則出現在 20 Hz 左右，屬於相對低頻的範圍，此外不同的量測地點會對土石流地聲訊號強度造成相當程度的影響。

關鍵詞：土石流觀測站、土石流防災應變系統、土石流地聲、顯著頻率。

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Development and Application of Automated Debris-Flow Monitoring System in Taiwan

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ABSTRACT This paper introduces the thirteen automated debris-flow monitoring stations in Taiwan established by the Soil and Water Conservation Bureau（SWCB）. The purpose of setting up these stations is to collect local field data and to help us understand the physical mechanisms of debris flow. Besides, these data can be utilized as references for designing debris flow disaster prevention constructions as well as academic research.

The automated debris-flow monitoring system consists of the sensors, the front instrument cabin, the transmission module and the back web-based real-time display system. The sensors include rain gauges, CCD cameras, wire sensors, geophones and ultrasonic airborne level meters. The operation of the system is in “normal mode” with a lower sampling rate at normal times. When the rainfall exceeds a specific threshold in the field, the whole system will automatically switch to “event mode” with a higher sampling rate. In the event mode, all the collected data will be promptly transmitted to SWCB Debris Flow Emergency Response Center to provide information for decision-making. Besides, specialists who are on duty in SWCB can change the operation mode and operate some on-the-spot instruments through the remote control module. The system is a “half-opened” one designed to expand for further necessities in the future in order to integrate the precious resources.

During the Mindulle typhoon period in July 2004, the first debris flow event was monitored since the automated debris-flow monitoring system was established in 2002 in Taiwan. The observation data showed that the discharge of the river decreased abruptly just prior to the appearance of the debris flow surge. Big boulders gathered at the front surges of debris flows and formed the wavy shape on the surface. A rapid decrease in flow depth appeared just behind the front. The velocity of debris-flow front was about 10 to 13 m/s. The depth of the front surge was estimated to be from 5.5 to 6 meters and the maximum diameter of the boulders in debris was from 4 to 5 meters. The average depth of the debris-flow surge was about 2 meters and the moving process of debris flows lasted for about 5 minutes. The Fast Fourier Transform (FFT) was adopted to analyze the ground vibration signals detected by geophones. The frequency range of ground vibration generated by debris flows was between 2 to 150 Hz and mainly between 5 to 50 Hz. The superior frequency appeared at 20 Hz and mainly belonged to the lower frequency range. Different locations of geophones would strongly affect the amplitude of ground vibration caused by debris flows.

Key Words: Debris-flow monitoring station, Debris Flow Emergency Response System, Underground sound of debris flows, Superior frequency.