Design and development of instrumentation network for landslide monitoring and issue an early warning

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CSIO, Chandigarh has designed and developed an instrument network around standard geo-technical and geo-physical sensors and advanced associated electronics. Network was installed in 2006 for continuous instrumental monitoring of the site at Mansa Devi near Haridwar. The paper highlights design approach for network and explains technical details of different sub modules. Network performance in terms of functional reliability, data generation capability and failure rate in the field has been evaluated and necessary design modifications have been incorporated.

Keywords: Geo-physical sensors, Instrumentation network, Landslides monitoring

Introduction

Landslides most often occur as ground water builds up in a slope due to rain, snowmelt or landscape irrigation. This water increases material weight in the slope, increases pore pressure, hydrates and expands clay minerals, dissolves minerals that may hold particles together, and decreases material strength; all of which weaken the slope. In every slope, stresses due to gravity exist and it increases with the slope height, slope inclination and unit weight of the material forming the slopes. Shearing stress also develops in surface zone due to thermal expansion, contraction/ shrinkage, freezing and swelling etc. When shearing stress along vulnerable and weak surface exceeds shearing resistance of the slope, a landslide occurs. Vibrations generated by movement of heavy vehicles create oscillations in rocks and thus change stress pattern reducing shear strength. Rainfall over some areas in Himalayan region is in excess of 200 cm/year and is a cause for landslides. Sometimes, people also contribute to the slope failure by diverting rainwater and roof water, which alters hydrology of the slopes. An important cause of mass movements or surface failure is the absence of surface drainage system or proper opening for seepage. This causes frequent occurrence of landslides during or after heavy prolonged rainfall.

This paper presents technical details of building modules of CSIO developed instrumentation network and its performance analysis.

CSIO developed Network for Landslides Monitoring

CSIO have successfully developed and configured an instrumentation network around state of the art sensors to monitor inclination of natural slopes, tilt of rock slope and surface deformation, amount of rain fall, anchor tensioning in retaining walls, deep rock movements, soil Stress, crack & movements in rock masses and water pore pressure and associated advanced field operated electronics. Instrumentation has been designed around modern data acquisition system, advanced signal conditioners, digital data communication links and necessary software. This complete system has been installed at Haridwar (Mansa Devi) active landslide site. The system is operational round the clock on solar panel and under observation from June 2006 (Fig. 1).

Design approach and Network Configuration

Landslide monitoring system[1-3] consists of: i) Field units (FUs) located within landslide zone; ii) Local control station (LCS) at nearby stable area; and iii) Central Data Recording & Analysis Centre. FUs along

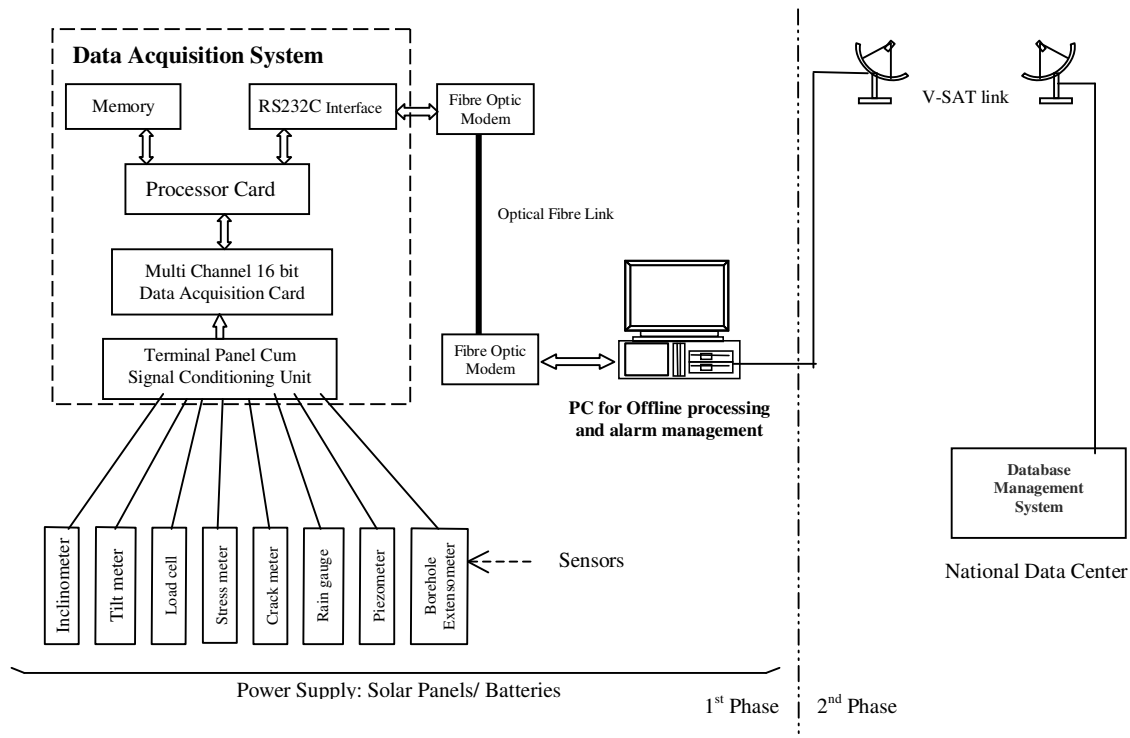———————
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Fig.1—Schematic diagram of developed system

with LCS make one independent system for a particular site. Data analysis and interpretation is done at local station to set various alarms and to detect likelihood of occurrence of any landslide. The network can be expanded to cover fairly large area simply by adding more number of FUs to LCS. Likewise, many independent area specific local networks can be hooked up to a master central recording and processing station via VSAT connectivity to form 'National Grid for Landslides Monitoring'

FU monitors an identified site by sensing and collecting data for a number of physical variables responsible for causing landslides in this area. Field station, basic sensing unit, records the data sensed by a set of geotechnical sensors, and transmits collected data in automated mode to LCS via optical fiber communication link. In case, failure of communication link between FUs and LCS, data can be retrieved from field station by connecting laptop through serial interface.

In CSIO system (Fig. 1), FUs essentially consist of signal conditioner cum sensor interface unit, 16-bit data acquisition module, optical modem, optical fiber, power supply, solar panels, charge controller, battery pack and sensors namely inclinometer, tilt meter, rain gauge, crack meter, extensometer, piezometer, stress

meter and load cell. The field unit has been hooked up with PC based control station to realize a full-fledged landslide monitoring system. All the selected components (cables, casing, sensors and other enclosures) are strong enough to withstand severe environmental conditions of landslide site under surveillance and remain operational round the clock over a very long time without quality deterioration.

Data Acquisition Module (DAM)

PC architecture based DAM[4,5] is main component in field station design. It uses Pentium based processor card, multifunction data acquisition card, advanced signal conditioner cum sensor interface unit and 64 Mbytes flash disk for data storage. PCI-20098C multifunction board is used as data acquisition board in DAM. Instrumentation software of DAM is developed in C language under MS-DOS environment. DAM is programmed and controlled for different tasks/ schedule through control software from LCS, which is about 1 km away from field station. DAM can record data from 80 sensors simultaneously, installed in landslide prone area.

Signal conditioner cum Sensor Interface Unit

This unit contains 80 analog input channels, 16 digital I/O channels and two event counting channels. Different sensors are connected to different analog input channels
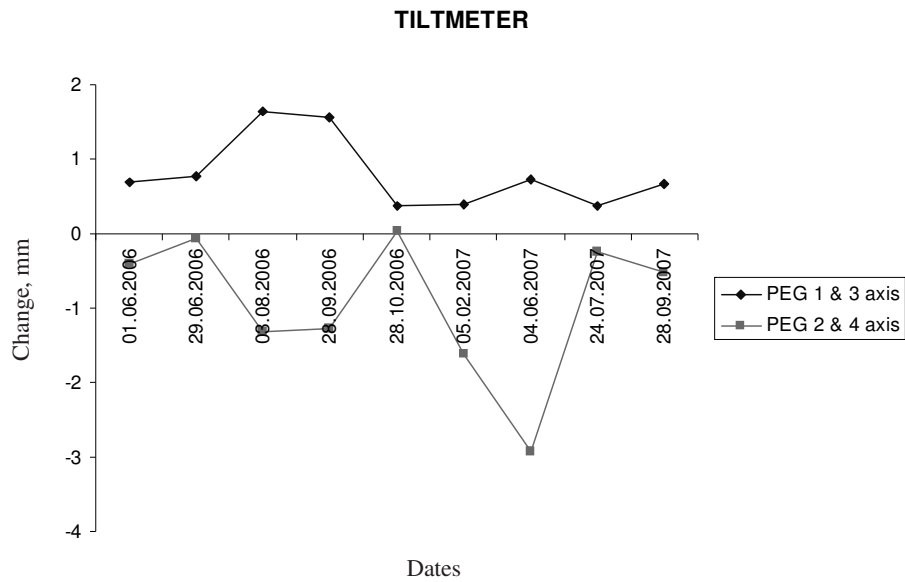
TILTMETER

Fig 2—Plot of tiltmeter data

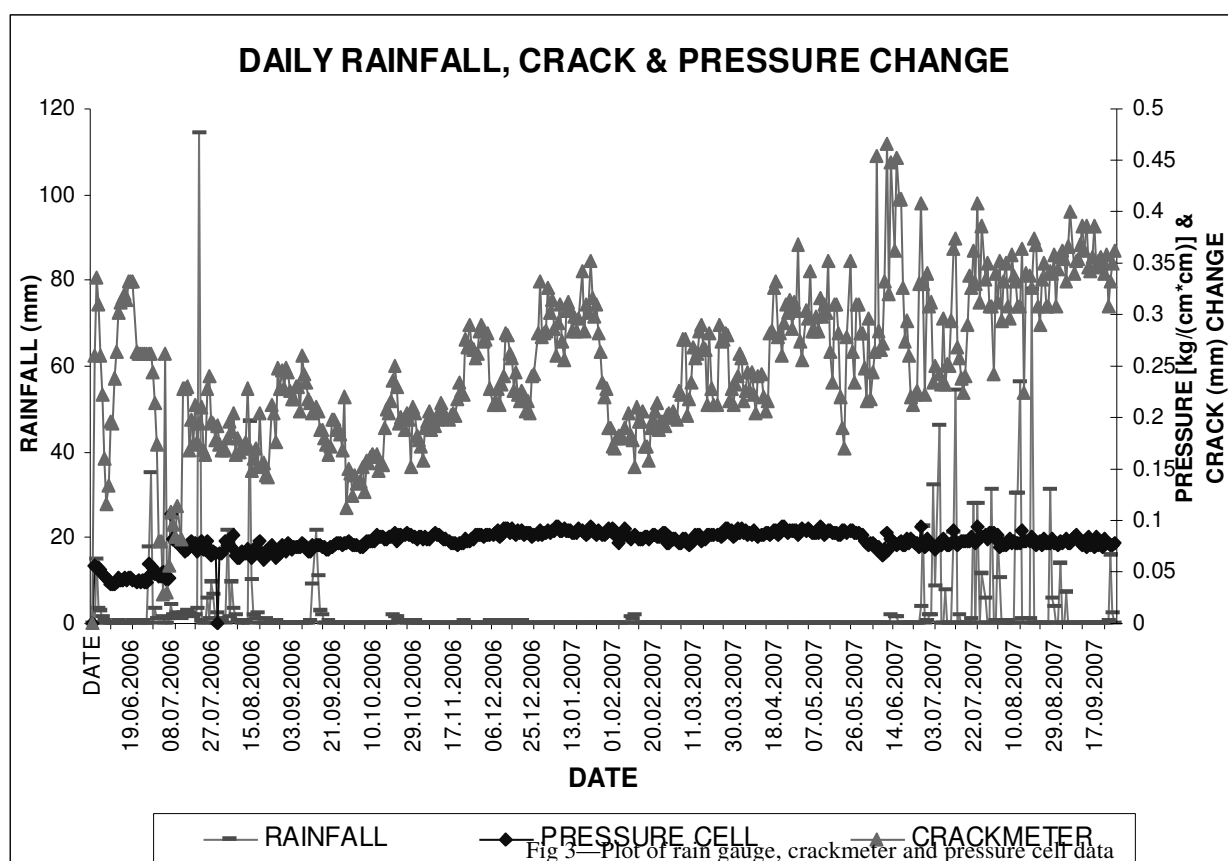**DAILY RAINFALL, CRACK & PRESSURE CHANGE**

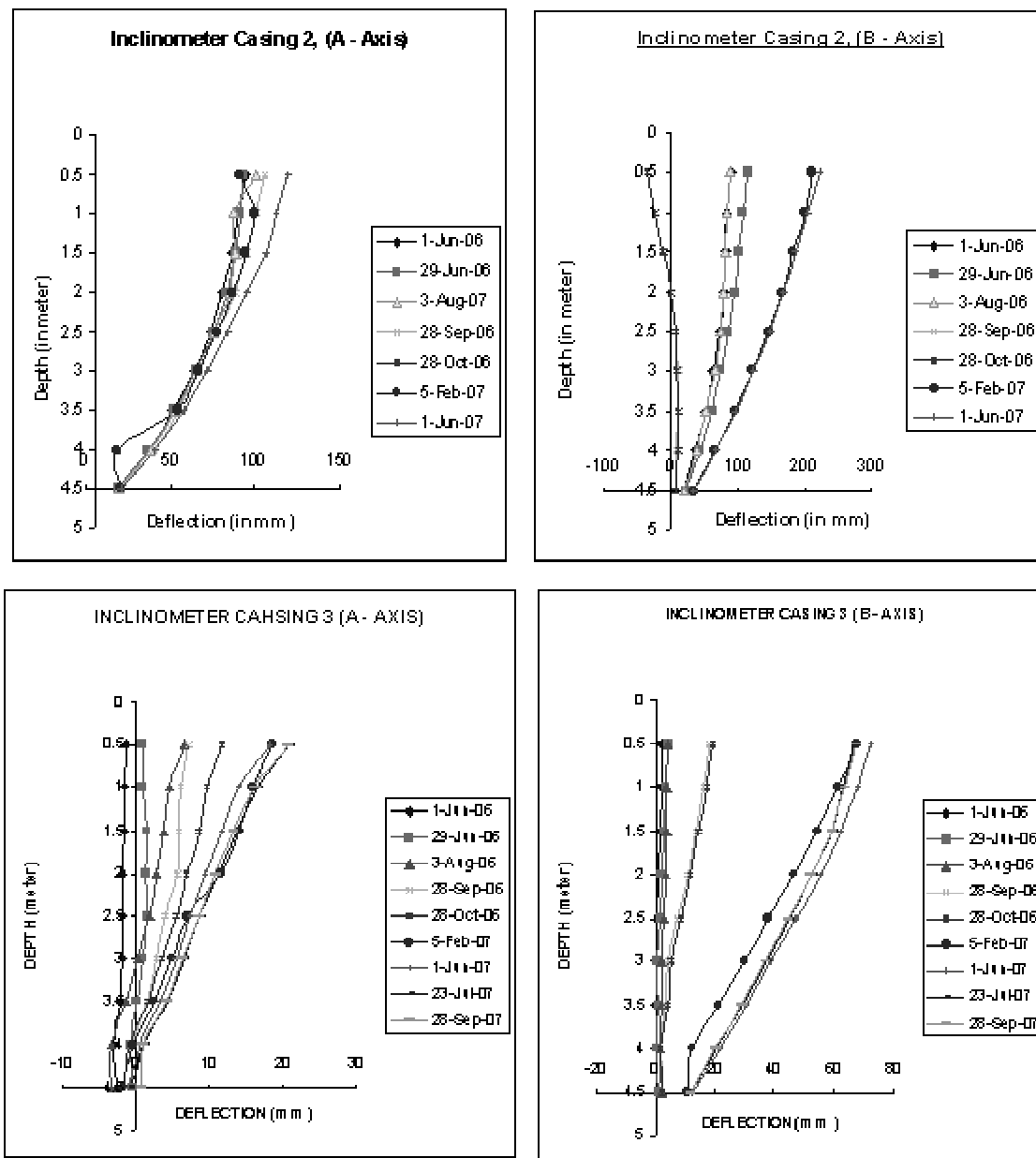Fig 3—Plot of rain gauge, crackmeter and pressure cell data

Fig 4—Plot of inclinometer casing numbers 2 & 3 data

for reading/ measuring of different parameters like inclination, tilt, stress, water pore pressure, load, cracks, extension etc. This unit improves quality of signal received from different sensors. Rain gauge is connected to 16-bit event counting channel for rainfall measurements.

PC Based Control Station

LCS[4,5] has been designed around personal computer (or laptop) and fibre optic modem. Optical fiber communication link has been incorporated between control station and FU. LCS has been designed to control

and program data acquisition module via optical fiber link. Control software has been developed to control/ program field station from LCS to actuate required commands such as start data acquisition, channel configuration (specifying sensor specific data for each channel), data acquisition scheduling, viewing individual data in real time, data download, trend view and shut down of data acquisition etc. LCS extracts, processes and analyzes received data from field sensors. Data processing and interpretation is done for issuing early warning. Data can be uploaded / transmitted to Central Data Center.

Optical Modem and Solar Panel

Optical modems, which convert fiber optic to RS-232/422/485 format, have been incorporated in design approach and are capable of full duplex transmission over a 2.5 km long optic fiber cable with baud rate selectable in between 1200 kbps & 115.2 kbps. Optical fiber cable is a multimode cable (3 mm chord, 2 fibers) having 3.5 dB/ km attenuation at 850 nm.

Solar panel module is flat arrangement of series-connected silicon solar cells and 30-36 solar cells per module have been used. Four panels (maximum power rating, 37.5 W/panel; rated current, 2.20 ampere/panel; rated voltage, 17.0 V_{DC}/panel) have been used to power complete FU. Panels are connected in parallel. Battery pack consists of two sealed lead-acid batteries of 12V, 150 Ah rating. Battery pack is charged through charge controller, which receives 18 V_{DC} input from solar panels and provides 13.5 V_{DC} output voltages. Battery pack provides 12 V_{DC} input voltage to DC-to-DC SMPS, which gives out ±5 V_{DC} and ±12 V_{DC}.

Results and Discussion

At present, data of five sensors (rain gauge, crackmeter, inclinometer, tiltmeter & earth pressure cell) have been collected by the network installed at Haridwar (Mansa Devi). Using this data, graphs showing variation in measured data with time have been drawn (Figs 2-4). It is observed that in rainy season, there is more tilt (Fig. 2), crack and pressure (Fig. 3) and inclination (Fig. 4). Pressure induced in the site may lead to landslide. For further study of this particular site, more data over long period is to be collected and analyzed at least for 3/4 rainy seasons. The good quality instrumental data collected in good quantity will enable to realize algorithms to calculate threshold parameters necessary to issue early warnings.

Conclusions

CSIO network is operational round the clock and data is being collected from June 2006 onwards. Based on available data, Haridwar (Mansa Devi) is rainfall induced landslide site. To issue an early warning on this site, more data is to be collected to calculate threshold parameters.

References

1   Hanna T H, *Field Instrumentation in Geotechnical Engineering* (Trans Tech Publications, Germany) 1985, 63-347, 718-720.

2   Dunnicliff J, *Geotechnical Instrumentation for Monitoring Field Performance* (John Wiley & Sons Inc., New York) 1993, 75-327, 443-451.

3   Moller B, Lindholh O & Arnekull S, Experience of a computerized monitoring system for landslides, in *Geotechnical Instrumentation in Civil Engineering* (Institution of Civil Engineers, Thomas Telford, London) 1990, 95-105.

4   Sweet C R & Matthews A T, Advantages of new data logging systems in the field of instrumentation, in *Geotechnical Instrumentation in Civil Engineering* (Institution of Civil Engineers, Thomas Telford, London) 1990, 607-616.

5   Kapur P, Mittal S K & Shamshi M A, Design and development of data acquisition system for land slide monitoring using virtual instrumentation, in *Conf Recent Advances in Process Control & Instrumentation Engineering 'RAPCIE 06* (Kurukshetra University, Kurukshetra) 23 Feb 2006.