WIRELESS MONITORING FOR CLIFF STABILIZATION AT LA CLUA (PRE-PYRENEES, SPAIN)

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SUMMARY

La Clua is a village at the foot of a conglomerate cliff (Pre-Pyrenees, Spain), eventually affected by rockfalls. After last big event, in 2009, that affected a house of the village, a rope net was installed to protect the village. In order to obtain information about the performance of the protecting net, but also to gain knowledge on the triggering mechanism a wireless monitoring system was installed. The system is equipped with sensors (4 crackmeters, 2 biaxial tiltmeters, 2 rope tension load cells and 2 thermistors) that are measuring the changes on two unstable boulders (one protected with the net, the other not). Sensors are connected to wireless dataloggers, installed next to the sensors and send data to the gateway. In this site, gateway is located 250 m far from the furthest logger, but thanks to the long range technology of the system, loggers can be up to several km far from the gateway and the data which is pushed to an internet server every 15 minutes. Preliminary results show that no relevant movements have been observed in the boulders, since February 2016. Only some slight changes of around 0.15º have been observed after heavy rainfall events in spring.

Keywords: wireless, sensors, Pyrenees, rockfall, stabilization

INTRODUCTION

The conglomerate's cliff at La Clua village is located at the Southern part of the Pre-Pyrenees, near the village of Artesa de Segre (Lleida). The cliff, that has more than 300 m of longitude, where three families of discontinuities are present. The two vertical ones are almost orthogonal, which provide the cliff of a columnar aspect. The stratification is subhorizontal with clay levels, that invidualize the columns in the vertical. The combination of the three discontinuities, helped by the effects of weathering, makes big boulders susceptible of being unstable.
In 2009 a large rockfall event occurred, during a heavy rainfall episode. The event affected a house of the village, which was partially destroyed [1]. According to the amount of boulders cumulated at the foot of the cliff, the open joints, clearly visible, and the evidences of recent instabilities, the rockfall risk at the village appears to be high.
After several studies at the site to evaluate the instabilities, several potentially unstable blocs were identified, representing a total volume of 1700 m3. The main unstable areas were selected and, considering the elevated risk they were producing over the houses and people in the village, some actions were taken to stabilize them.

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a) b)

Figure 1: a) Aerial view of La Clua, and location of La Clua in Catalonia's map; b) Event occurred in 2009, it can be observed both the source area at the cliff and the affected house.

Punctual actions were carried out in three main unstable areas: a flexible stabilization system (SPIDER®, [2]) consisting in a spiral rope net made from high-tensile wire was installed covering the selected unstable area. Large flexible anchorages are fixing the net. The mission of the whole system is to increase the safety factor of the potential unstable boulders, which was close to 1. Additionally to the net installation, a wireless monitoring system was installed.

LONG RANGE WIRELESS MONITORING SYSTEM

The long range wireless monitoring system has a threefold purpose: a) to identify the triggering factors and the mechanism of instability, b) to study the behavior of the protecting elements and c) to get preliminary data for the design of an Early Warning System based on the monitoring of the triggering factors and protecting elements. The system consists of 4 analog dataloggers, reading data from a variety of sensors, and 1 gateway, equipped with wireless communications of very long range. In order to perform the purpose b), some part of the sensors were installed in the protected area, while others were installed in boulders where no protecting action was taken, so that the effect of the proteccting elements can be analyzed.

In Boulder 1 (no protecting net installed), 2 crackmeters, 1 biaxial tiltmeter and 2 thermistors, were installed. In Boulder 2 (protected), 2 other crackmeters, 1 biaxial tiltmeter and 2 rope tension load cells (installed in the horizontal wires that are reinforcing the protecting system) were installed. Sensors in Boulder 1 are located in two different locations, connected to two analog wireless dataloggers. All the loggers read and store data from sensors and send it to the gateway [3].

The long range radio technology that this system uses is based on a frequency band of 868 MHz. Thanks to this technology, the gateway can be installed up to 15 km far of the loggers (in best situation). In this specific project, gateway was placed in the front wall of one of the houses of the village, 250 m far from the loggers in Boulder 1 and Boulder 2. The gateway is powered by the standard electrical power, and it is connected to the internet using a GSM SIM card. The gateway has an embedded software, available for the user through a tunnel in a server. The software permits to visualize the data, download it, see the performance of the radio communications, but also permits to change the sampling rate of the sensors remotely. Thanks to this software, data can be automatically pushed to a FTP server, every 15 minutes.

a) b)

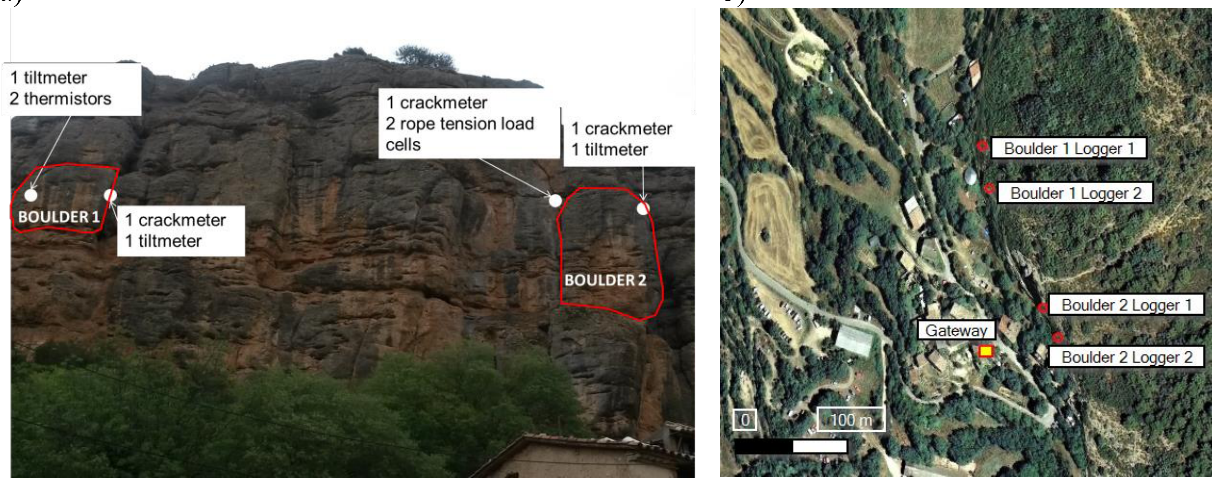

Figure 2: a) Location of the sensors at the cliff. Boulders 1 and 2 are identified; b) aerial view of the site. Gateway and loggers are located.

FIRST PRELIMINARY RESULTS

Installation of the monitoring system finished on February 2016. Since then, data sampling has been done with a hourly frequency for all the sensors. No rockfall event has occurred since then, neither in the protected nor the unprotected parts. Analysis of data series has been performed and some preliminary results can be highlighted.

On one side, no movement in the cracks other than the daily oscillation due to temperature has been observed. Also the rope tension load cells are showing daily oscillations due to contraction-retraction of the steel (Figure 3).

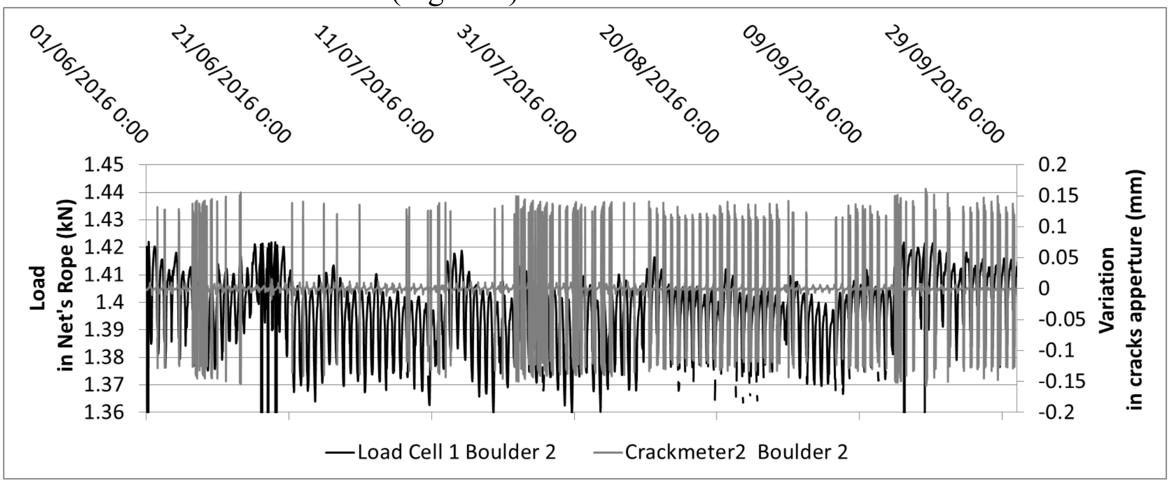

Figure 3: Data from Load Cell 1 in Boulder 2 and Crackmeter 2 in Boulder 2 from June to October 2016.

The tiltmeters did not show relevant movements along time, only some specific events when the tilt increased. Some of these events were correlated with rainfall data from a nearby meteorological station (Baldomar, from the public network, Figure 4). Between 9th and 13th of May, a special event was detected. A daily cummulated rainfall of 38,4 mm was detected. This rainfall episode had a maximum hourly precipitation of 12,3 mm. The correlation between the rainfall and the delayed movement of the boulder has been observed.

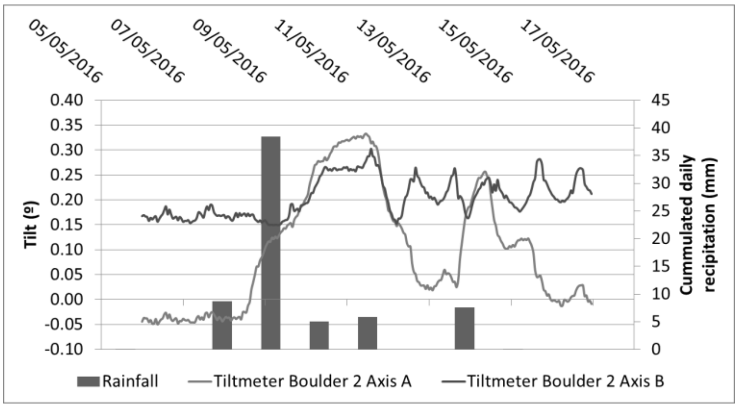

Figure 4: Correlation between daily cumulated rainfall in Baldomar (nearby station) and tilt in Boulder 2.

CONCLUSIONS

Wireless monitoring systems are a suitable system for remote monitoring in situations where wired systems are difficult to install, such as rockfall prone sites. The wireless long range radio communications make possible to have data from sensors spread in a extense area remotely available. Data collected in La Clua since February 2016 is the beginning of a dataseries that will be completed after a period of time and that will permit to develop an early warning and alarm system for the rockfall prone cliff.

Triggering mechanisms of the instability have still not been clearly identified, but the correlation between the rainfall and some small episodes of movement in the tiltmeters has been detected.

ACKNOWLEDGEMENTS

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