Integrating wireless sensor network for monitoring subsidence phenomena

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The Sallent Site

The Estació and Rampinya in Sallent neighborhoods are located within the former exploitation limits of the old underground potash Enrique mine. During the exploitation process the mine suffered several water floods (figure 1) that affect the viability of the mine. In 1954 a large natural karst with 28m of diameter and 110m height cavity was located. The great difficulties of controlling the flooding led to the closure of Enrique Mine in 1973.

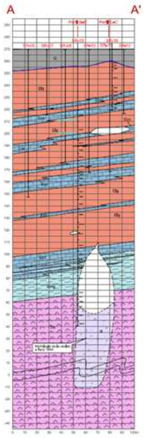
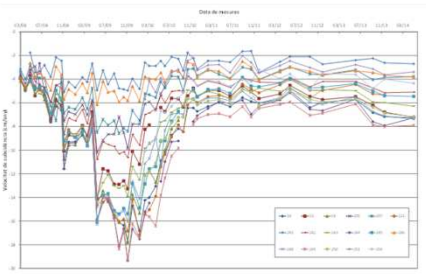


Figure 1. Detailed geological longitudinal profile scale 1:10000: including karst cavity and boreholes. Es Sodium and Potassium Salts, Emg Grey marls, Elg Siltstones and sandstones, Ecc Gray limestones, Elx Siltstones and gypsum, Q Clays and alluvial gravels, R Dump.

in the 1990s damage to several buildings was reported in the Estació neighborhood and so the Geological Institute of Catalonia (ICGC) started a studies to determine the origin of the damage, monitor the phenomena and propose solutions to guarantee the population's safety. Studies conducted have concluded that generalized subsidence is linked to the exploitation of mine Enrique and the "Big Cavity" located in SW of Estació neighborhood.

The implementation of a wide network foreground auscultation has allowed monitoring the process of subsidence since 1997. This network mainly consists of: A high-precision topographic leveling network to control the subsidence in surface; ii) a rod extensometers network to monitor subsurface deformation; iii) an automatic Leica TCA Total Station to monitor building movements.



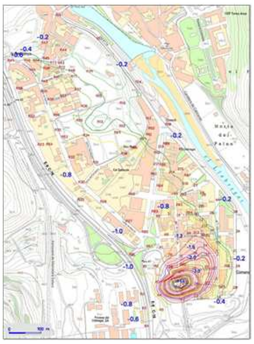


Figure 2 (up) Subsidence velocities of the closest points to the area of maximum subsidence, from March 2008 to May 2014.
Figure 3 (left). Distribution in plant of subsidence (IGC,2008).

Those networks were implemented within an alert system for an organized an efficient response of the civil protection authorities in case of an emergency. The alert triggering levels for the plan are defined on the basis of deformation rates in the critical area.

In December 2008 the control networks showed a significant increase in the speed of subsidence. This situation led to the activation level of alert in the emergency plan and the meeting of different groups in order to assess the activation of the plan. Finally, the preventive evacuation of about 120 residents from 43 homes in the neighborhood was done.

Figure 4. Image of Sallent site: 2010 view (left image) and 2015 view (right image) with most of the building demolished

The WI-GIM project

An innovative wireless sensor network (WSN) for the 3D superficial monitoring of deformations (such as landslides and subsidence) is being developed in the frame of the Wi-GIM project (Wireless sensor network for Ground Instability Monitoring - LIFE12 ENV/IT/001033).

The surface movement is detected acquiring the position (x, y and z) by integrating large bandwidth technology able to detect the 3D coordinates of the sensor with a sub-meter error, with continuous wave radar, which allows decreasing the error down to sub-cm.

Wi-GIM system is designed for continuous measurement 3D movements of the ground surface. For this reason, the conventional network measurement system more suited to validate WI-GIM system is the Leica TCA network, which measures automatically the movement in 3D. The TCA network measurements (vertical displacements) are supported by high precision topographic leveling (HTPL) measurements. This network (with high distribution density) provides a good overview of the distribution of movement, crucial to identify the location for TCA prisms and WI-GIM sensors (figure 5). The final configuration of the conventional monitoring system adaption to Wi-GIM system will be composed by:

- Twenty-five (25) Leica prisms.
- Around one hundred (100) points monitored by HPTL on demand.

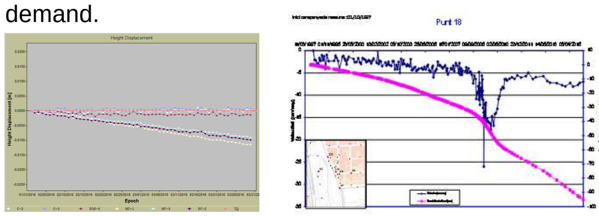


Figure 5. Conventional monitoring system in Sallent. (left) TCA prism measurements of control point and maximum subsidence area. (right) HPTL measurement of point located in the maximum subsidence area.

The Wi-GIM system requirements and finally configuration defined are (Figure 6):

- Master Node (MN) and Super Master Nodes (SMN) sensors equipped with continuous wave radar in order to improve the system accuracy of about one order magnitude.
- Slave Nodes (SN) sensors, installed within the subsidence area, at an optimal distance from the master nodes of 60-70 m.
- Passive Radar Slaves Nodes, (SN-R) also Slaves Nodes equipped with specific passive radar reflectors, an optimal distance of about 100-150 m.

Figure 5 (up) Different components that compose the WI-GIM sensors: Radar device, decaware (radio sensor), master/slave node box, battery, communication modem (for master nodes) and GPS antenna (optional). (above, left) Wi-GIM system distribution for Sallent site. (above, right) Wi-GIM sensors installed in Sallent test site.