RMS - Remote Monitoring System: GPS application on an Harbour Structure

Luca Manetti
GEODEV SA Earth Technologies, Switzerland

Abstract: This paper describes a long-term monitoring before, during and after the reinforcing works on the "Duca di Galliera" wave breaker in Genoa (Italy). A generic monitoring system called RMS – Remote Monitoring System has been developed by GEODEV and it's GPS extension has been selected for this application. The wave breaker has been instrumented with 10 autonomous RMS GPS sensors, while two RMS GPS reference stations have been installed on the roofs of two city buildings. Each RMS station consists of a weatherproof box containing the electronic components, the GPS receiver and the cellular modem, GPS antenna, solar panel and battery. A Control Unit provides for full automatic operation and remote control of operational aspects of the system. Measuring constantly the distance vectors between the reference and the measurement stations it is possible to determinate the displacements of the measured points and the relative deformation of the structure with subcentimeter resolution. This paper introduces the functional principle of this GPS-based monitoring system RMS, illustrate the main characteristics of the measurement stations and the Control Unit and presents the obtained measurement results.

1 Introduction

The "Duca di Galliera" wave breaker is a 1 km long segment of the ancient structure protecting the pier, being built in late 19th century in front of the Genoa harbor, Italy. Recent inspections have lead to conclusion that the wave breaker has to be strengthened with new concrete layers. In order to perform this operation

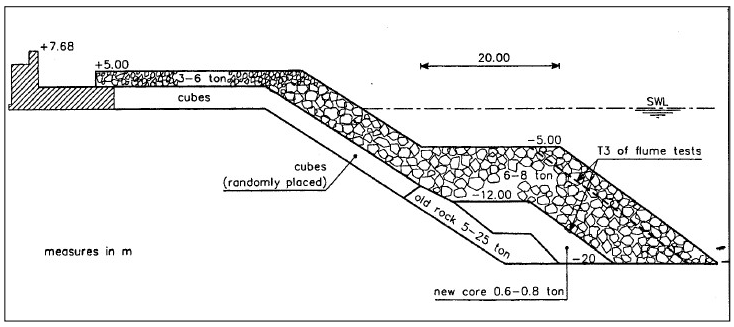

Figure 1: Section of the wave breaker with existing protective

Figure 2: Reinforcement works

safely, the authorities of the Genoa harbor decided to perform long-term monitoring before, during and after the reinforcing works.

The cross-section of the wave breaker is presented in Figure 1. The reinforcement works are presented in Figure 2.

2 The RMS monitoring network

The monitoring network is composed of 12 RMS Measurement stations. In these 12 measurement stations with the same hardware configuration, ten are used as movement sensors called rover Measurement Stations and two are assigned as reference points called reference Measurement Stations. The ten mobile stations, MobC to MobN from east to west, are distributed along the 1 km wave breaker (see Figure 3). Two reference stations, RefA and RefB, are located in fix and steady positions. RefA is located at Lat 44º 24' 23.37", Log 8º 53' 41.856" and Height 29.372m. RefB is installed near the Control Unit at the University of Genoa at Lat 44º 23' 58.514", Log 8º 57' 47.629" and Height 111.374m. The distance from RefA and RefB to the monitored structure is about 3.5 to 4.5 km and the distance between RefA and RefB is about 5.5 km. The communication links between measurement stations and Control Unit is based on the cellular network (GSM).

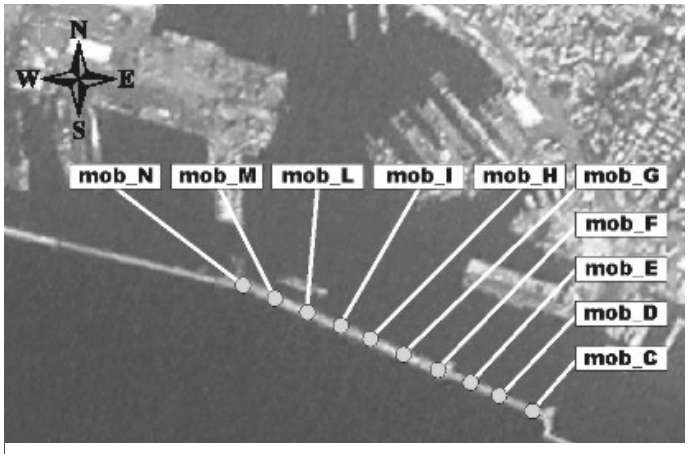

Figure 3: Top view of the 10 measurement stations network on the wave breaker.

The top view of the rover stations is presented in Figure 3.

3 RMS measuring stations and Control Unit

3.1 Measurement stations

The hardware configuration of each measuring station includes:

- Weatherproof box (IP66 standard) with GPS receiver and electronic devices
- Communication architecture including GSM communication modem and antenna
- Power supply architecture consisting of solar panel and rechargeable battery
- GPS antenna with protection radome

Figure 4: GPS reference station at the University

Figure 5: Fully equipped GPS measurement station on the wave breaker

Due to the particular extreme conditions of this installation (sea water, waves and storms, strong winds), the RMS measurement station boxes (standard dimensions 15 x 20 x 30 cm) were fastened inside bigger protection boxes anchored to the wave breaker structure. One of the rover stations installed on the wave breaker is presented in Figure 5, while Figure 4 shows the reference station in the University of Genoa.

3.2 Control Unit

The Control Unit, presented in Figure 6, is used for central control of the RMS network. The main tasks of this device are:

Figure 6: Control Unit

- Continuous run of the scheduled measurement plan
- Management of each measurement station
- Automatic download of the GPS raw data from each measurement station
- Automatic batch processing of the GPS raw data

- Visualization of the resulting monitoring data and of the measurement specific parameters
- Server tasks for the remote Internet access and file download/upload

4 Automatic measurement and data post processing

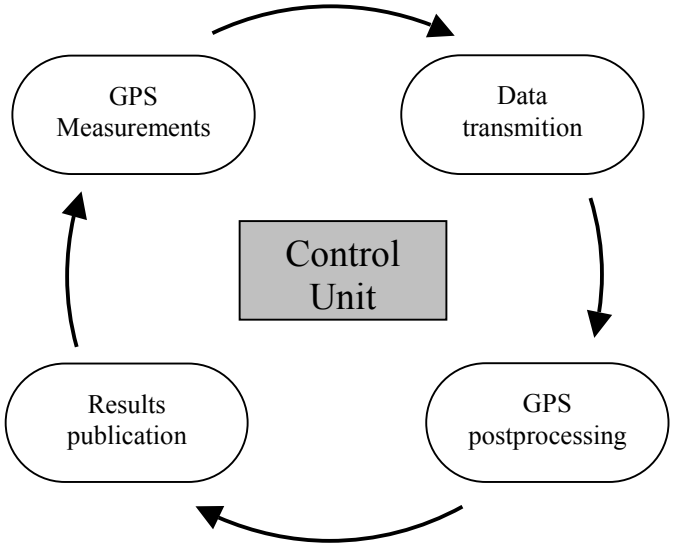

Figure 7: Control Unit automatic activities flow

Measurements of all measurement stations are executed at the scheduled times. The running schedule and system parameters can be configured though the Control Unit on site or off site through and Internet connection taking advantage of the server capabilities of the Control Center software.
Four measurements per day are carried out in this project performing 20 minutes of GPS raw data acquisition at 0.1 Hz. All the measurement stations work simultaneously and store L1 phase data from the GPS satellites. Consequently after each data acquisition, each measurement station waits for the call from the Control Unit for the data download. The GPS data post processing runs automatically at the scheduled time after the last measurement and data download. The post processing gives the current position of each rover measurement station related to the reference stations positions and to the monitoring starting day in local East/North/Up coordinate system. A daily averaged value is computed and published every day on the web site.
In addition to measured GPS data, the transferred information also include important parameters of each measurement station such as internal temperature of the box, battery charge level, solar panel activity and temporary consume of the electronic devices. Such information is crucial for analysing the health behaviour of the remote and inaccessible measurement station.
The monitoring results can be displayed locally on the Control Unit software and published as interactive web pages and viewed with any standard web Browser.

5 Monitoring results

After 22 months of continuous monitoring, the measurements show a strong correlation between the reinforcement works and the slow displacement of the structure. The Northeast tilting of the wall (see Figures 8 and 9) coincides with the dumping activities on the landside of the wave breaker of June '02 (see Figure 2). In particular, while the external parts of the structure (points *MobC*, *MobD* and *MobN*) can be considered as stable, the internal points show a clear displacement toward landside. A vertical ditching logically follows this horizontal displacement.

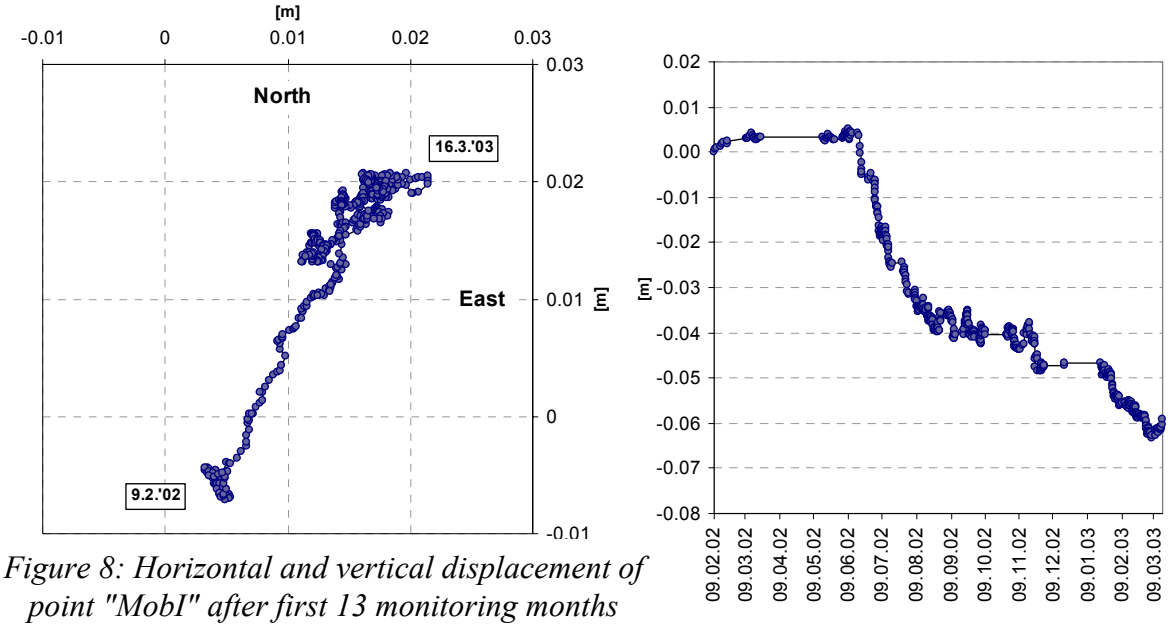

Figure 8: Horizontal and vertical displacement of point "MobI" after first 13 monitoring months

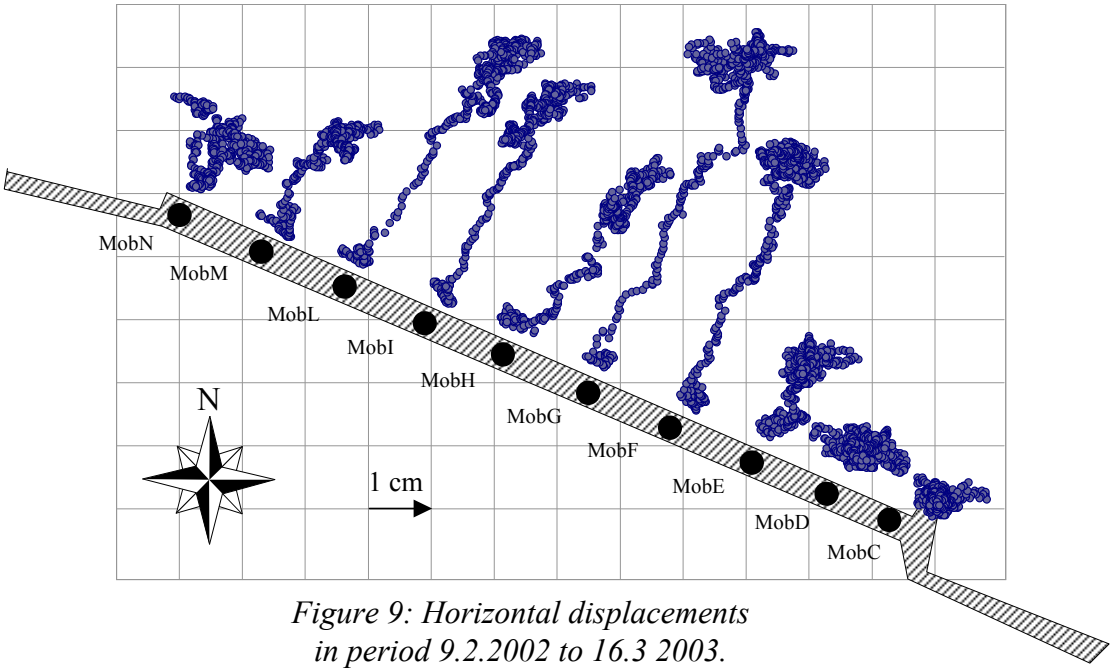

Figure 9: Horizontal displacements in period 9.2.2002 to 16.3 2003.

6 Conclusions

The RMS system was successfully installed and operated in harsh and aggressive conditions, running automatically since about two years independently from human intervention. The harbor authority accesses to the monitoring data in near-real time using a standard Internet browser getting important and accurate information regarding the structure behavior during the reinforcement process.

The monitoring results confirm that RMS Remote Monitoring System is suitable for such an application providing an easy and reliable manner to track 3-D low dynamic displacements of structures such as bridges or dams, or of natural objects such as landslides or earth settlements.

Furthermore the RMS system hardware and software architecture was conceived and designed as a general data acquisition and sensor/instrument remote management solution. Basically any kind of RS-232 instrument as well as analog/digital sensors can be interfaced to an RMS measurement station and integrated within the system.

At present, following monitoring devices are already integrated with the RMS system and are successfully operating within monitoring projects: GPS receivers, laser distance meters, infrared thermal imaging cameras, peizometers, soil moisture sensors and generic dataloggers.

References:

KNECHT A., MANETTI L.. 2001. Using GPS in structural health monitoring. Proceedings of the SPIE's 8th Annual International Symposium on Smart Structures and Materials. Newport Beach (CA). USA. [4328-12]

MANETTI L., Knecht. 2002. GPS-based System for autonomous and permanent monitoring of large structures. First International Conference on Bridge Maintenance, Safety and Management. Barcelona, Spain.

MANETTI L., FRAPOLLI M., KNECHT A., 2002. Permanent, autonomous monitoring of landslide movements with GPS. 1st European Conference on Landslides. Prague, Czech Republic

Author:

Luca Manetti
GEODEV SA Earth Technologies
P.O. Box 341
6928 Manno, Switzerland
luca.manetti@geodev.ch