

REAL TIME VIBRATIONS MONITORING (SPPV) AND AUTOMATIC ALERT NOTIFICATION

1. Introduction

The purpose of this system is to record vibrations in buildings being caused by human activity or construction works, for example industrial vibrations or construction/demolition works that may be carried out in the monitored building's neighborhood. The monitoring is performed in real time 24/7, and it is intended to analyze the velocity spectrum and calculate velocity magnitude of the movement of the building. The user can make decisions about actions that have to be taken for reducing the level of the vibrations in order to protect the under monitoring building.

2. Vibrations Monitoring

This article concerns the monitoring of the vibrations of an ancient structure whose floor plan is shown in Figure 12. New highway works are performed nearby the ancient building and it must be protected if high vibrations will occur. A new road tunnel is going to be constructed below the building, therefore vibrations caused by the construction works and later by the traffic of the road, have to be monitored.

Figure 12 (attached at the end) shows the position of the sensors. The final position is decided after a technical study of the structure that has been performed by the civil engineers, and therefore sensitive positions were defined. The contour of the building's footprint is depicted in green. The proposed positions are presented in blue. This selection follows exactly the recommendations posted in the mentioned technical report.

They are in details:

- Two (2) positions along the large wall, one (1) on each side of the transverse wall, at the surrounding ground place, approximately 2,00 m from the wall.
- Two (2) positions, respective and conjugate to the previous ones, to the foundation ground of the wall, just next to it, at a distance of not more than 0.25 m, and
- Two (2) places on the cornice of the vaulted construction of the building, approximately 2,00 m (approximately).

The system, as mentioned above, operates continuously, that is, the user can receive the real-time velocity data, and set activation levels. Thresholds for each sensor can be set separately. If the threshold level will be exceeded by the amplitude of the oscillation caused by the nearby activities, alert messages will be generated and be sent until the velocity level falls back below the activation limit. All log information (log files) from all channels is recorded from the datalogger and is available for one month period. Then, old log file will be replaced by new one and the old log file will be stored as a backup file. The next month it will be replaced by the new log backup file which means that the user will be able to access current log information plus the previous moth log information. Older log information will be permanently deleted.

3. Instruments

The recording system consists of the following parts: three-axis velocity sensor, seismic digitizer, central datalogger as well as the necessary power supply and surge protection equipment. Analytically the instruments were used in this application are:

3.1. Seismic Sensors

C100 type sensors (Fig. 1 and 2), which are 3 channel seismic sensor type, velocity equivalent output having a strong outer Kevlar cable for protection against mechanical stress and humidity. The sensor ranges from 0.005 mm/sec to 100 mm/sec, and has frequency response from 1 Hz to 300 Hz and a dynamic range 138 dB. Two types of the sensor were used based on installation requirements, a surface type and a borehole type.



Figure 1: C100 borehole sensor



Figure 2: C100 surface sensor

3.2. Seismic Digitizer

The digitizer of the application (Figures 3 and 4) is the SRi32S datalogger unit which supports three seismic channels digitizer unit, local recorder and real-time data transmission over the seedlink protocol. It also supports GPS receiver for providing precision timing. The unit has low power consumption so it can operate continuously for many days getting powered a 12-volt battery



Figure 3: Sri32S digitizer/recorder

Figure 4: Sri32S digitizer/recorder back view

3.3. Central Recording System

The central recording system (Figure 5) consists of a small linux PC which supports industrial type hardware to withstand outdoor conditions. It has low power consumption, it does not requires cooling fans, and provides all the necessary peripherals for collecting, storing and transmitting the data from the interconnected digitizers in real time.



Figure 5: Central recording PC

3.4. WiFi router

The wifi router serves to send the data in real time to multiple acquisition centers. Real time processing and analysis of the vibration signals can be performed by the automatic processing software "GEOShock" developed by GEObit [3].

3.5. Central Recorder PSU

The recorder is powered from a switching power supply unit similar to those that the computers have. The reason we used this solution is the low heat emission. The instrumentation is placed into a metallic 1m X 0.8m X 0.4m box, in the field, directly exposed at the sunlight. We had to avoid any possible overheating inside the box during summertime. The PSU provides also battery back-up line (thus operating as UPS) so in the event of a power failure, the datalogger continues to run getting power from the battery. A battery pack of total 120Ah capacity is used to ensure one week of operation in the absence of electricity.

3.6. Digitizer's PSU

The power supply of the digitizers is provided by a 12-volt 120Ah battery pack, which is keeping in charge by a switching-type 12v battery charger. The reason of using this is again the low heat emission. Additionally, for safety and isolation reasons, a 12Vdc/12Vdc, 2k5V isolated DC-DC power supply module is connected to the power input of each datalogger.

Given the low power consumption of each digitizer, the system can operate for one week in the absence of electricity getting powered from the batteries.

3.7. Surge Protection

A very important issue of this installation was the system protection against of any type overvoltage or electrical spikes generated or propagated from the long power line. It is important to note that the system is getting electricity through an 600m electricity cable, laid on the ground. This is because the closest electricity point was 600m far from the installation place. A variety of protection techniques have been applied for avoiding any problems.

The most basic and important protecting element of the system is the local earthing consisted of three copper bars, one meter length each, pegged in the ground in a triangular arrangement. This is the main ground point of the system. At the end of the supply line and close to the instrument's shelter, a 10A self resettable fuse is placed, followed by an overvoltage and lightning protection device. A 220/220V , 200W power transformer is then connected to isolate the long electricity line from the local electricity loop. At the transformer's output, a second lightning surge protection is placed followed by voltage monitoring device, with 1500VA power handling capability. The voltage monitoring device is connected to a plumber, and the chargers and the power supplies are connected there. Overvoltage protection is also placed on the Ethernet line of the wifi router to protect the system of any possible overvoltage of the WiFi antenna.

4. Installation

The sensors that are placed at PER1 to PER4 positions (Figure 12) are borehole type and have been settled into a shallow hole (small post hole) in the ground. The PER5 and PER6 sensors, being placed in the coronation, are surface type. The cables have been passed through flexible plastic protective tube and have been connected with the digitizers into the shelter. The shelter is a metallic box suitable for outdoor use that has been designed to accommodate the instrumentation. The box was placed at a distance from the ancient structure, and grounded on using quick dry cement. No excavation were applied at all..

Surface sensors were attached at the wall with quick dry cement as well, and the borehole type sensors were secured to the ground into the postholes using sand.

The position of the sensors as it is shown, is made accordingly to the technical study and shown in Figure 12



Figure 6: Surface type sensors



Figure 7: borehole type sensors



Figure 8: Installation



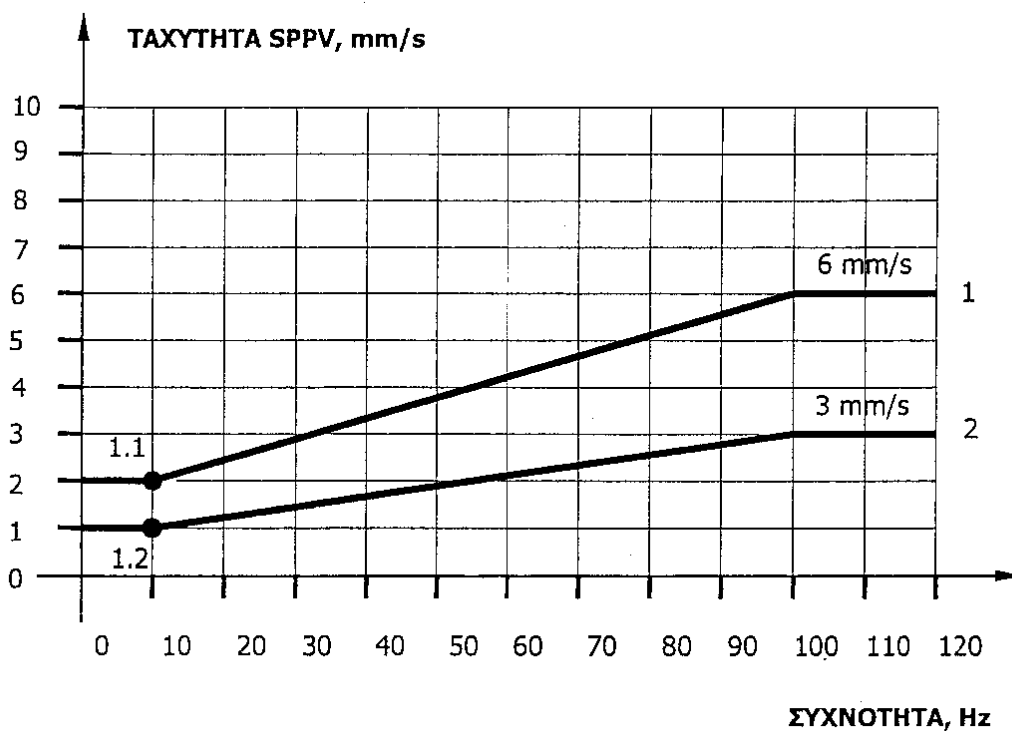
Figure 9: Monitoring System shelter.

5. Automatic real-time ground vibration velocity calculation (SPPV) - Software (GEOShock)

The communication and analysis software (GEOShock) is running on a linux pc, licensed for unlimited users, with the following features: Signal waveform plot, FFT analysis, spectrum response, energy content per frequency, file conversion in ASCII format, individual trigger level set of each sensor, alert via e-mail or sms when SPPV exceeds predefined limits etc. The software can be installed into any computer and thus the user can receive data in real time and have them processed in multiple receiving points. The software communicates with the data plot software "SeisGram2k" and the SPPV monitor.

The implementation of the software has been developed in a such way that it provides continuous monitoring and recording of the vibrations in real time and in parallel vibration calculation at every minute and how many times the SPPV limit has been exceeded (if so). The SPPV limit is set according to the diagram of figure 10. The SPPV limit is not constant but linear to the frequency from 10 to 100Hz and it has been derived from the structural study of the ancient building.

The software has the ability to send automated email notifications to the user in case of exceeding the limits.



Picture 10: SPPV threshold limit.

6. System Operation

When the instrument installation was completed and the central datalogger was connected to the internet via the wifi router, the recording quality was verified remotely. The data were received at the GEObit's office and in parallel at the user's office in real time. The waveforms of the sensors are presented in real time in Figure 11

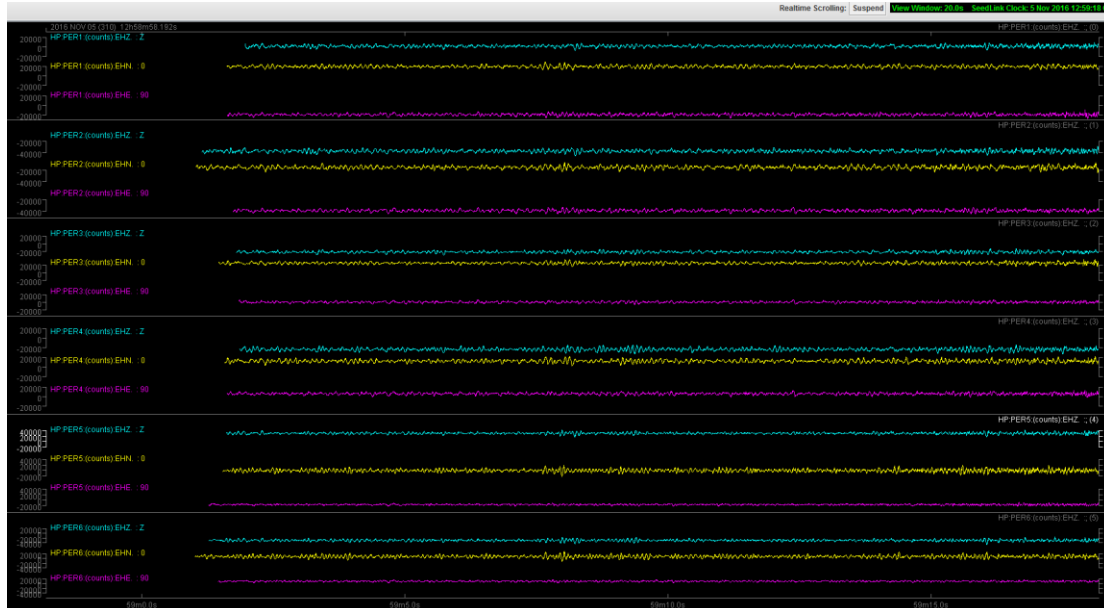


Figure 11: Real time velocity waveforms from the six sensors (18 channels)

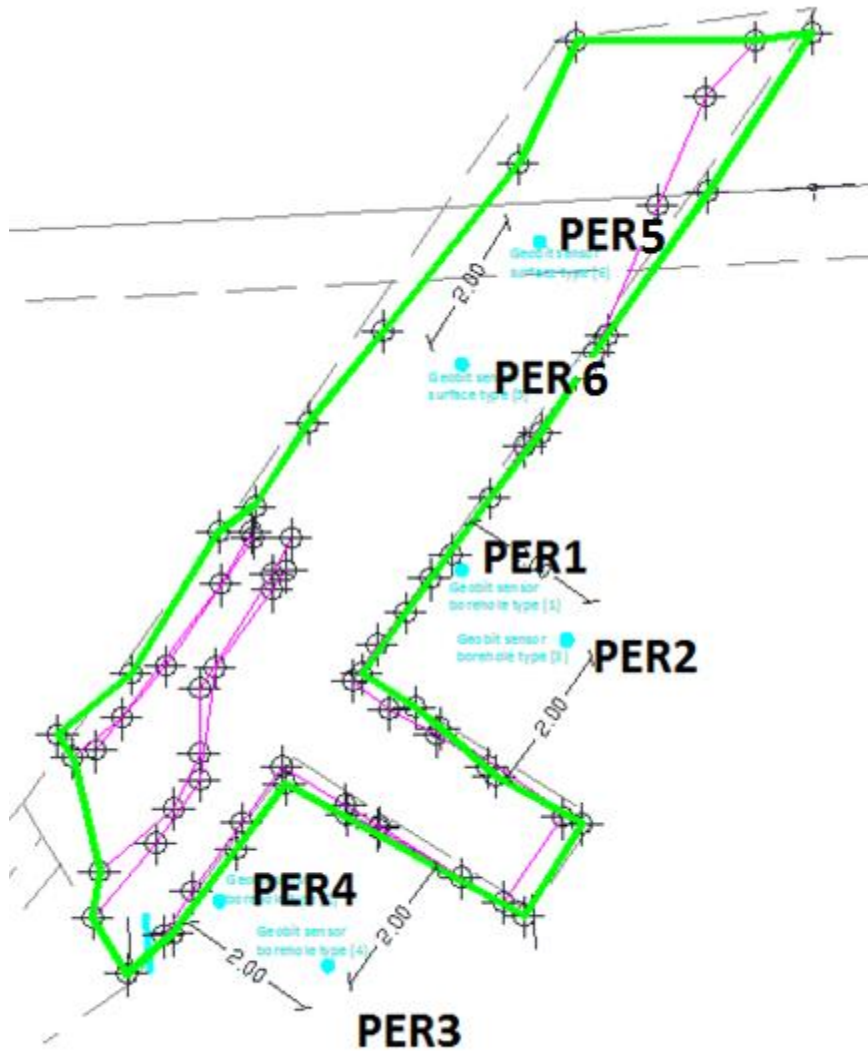
One data trace is displayed for each channel individually in the viewer. Each channel represents one component of each sensor. Channels named as "EHZ" represent the vertical (Z) components of each sensor. Channels named as "EHN" represent the Y (north-south) components of each sensor, and the channels named as "EHE" represent the X (east-west) components of each sensor (ZYX = orthonormal axis system).

Each digitizer is connected to a three-channel sensor and therefore it produces three EHZ, EHN, EHE waveforms.

Each sensor is named according to its position. We have data named 6 from the sensors like PER1, PER2, PER3, PER4, PER5, PER6. The location of each sensor is

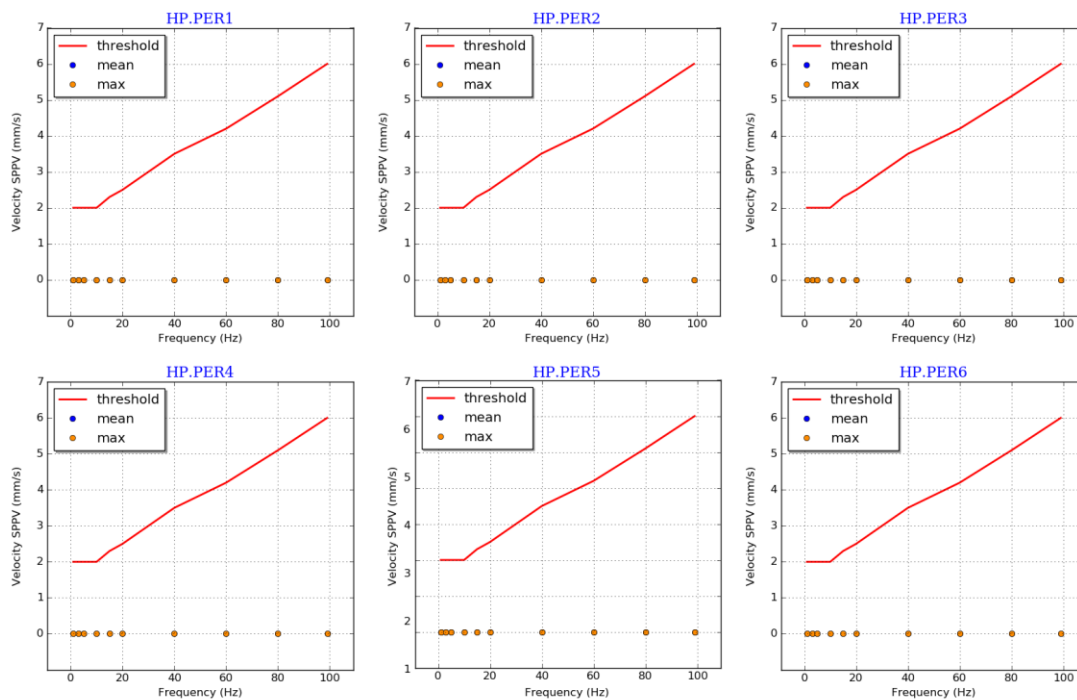
Name	Position
PER1	posthole – Northern, close to the building
PER2	posthole - Northern, 2m distance from the building
PER3	posthole - Southern, 2m distance from the building
PER4	posthole - Southern, close to the building
PER5	Surface mount –Northern upper part of the building
PER6	Surface mount –Southern upper part of the building

Table 1: Sensor positions



Picture 12: Sensor placement

The SPPV velocity calculation is automatically performed from the monitor service program **GEOshock** that processes the data in real time, calculates the SPPV magnitude and displays it in a plot as function of frequency. It also plots the maximum SPPV value that is calculated every minute. If the SPPV threshold is exceeded, the user receives an alert e-mail containing the maximum value that exceed the threshold.



Picture 13: SPPV vs frequency

7. Conclusion

GEObit instruments are flexible and can be used in many applications. Structural monitoring can be performed using GEObit instruments. Apart of the instruments use, several important technical issues had to be resolved at this application. The greatest issue was the electrical system protection because of the bad and temporary electricity supply. The system was installed late September 2016 and during the winter 2016-2017 there were no operational or supply problems. The protection worked well, even the system had to operate under strong thunderstorms at wintertime. Data transmission was over wifi router. The data have to be transmitted for long distance (6km) over wifi, for reaching the internet point and therefore being shared to different acquisition/processing centers. Three acquisition/processing centers are running in parallel, one at archaeological authorities' office, one at the construction's site office and one at our office for attending the system and produce the backup data.

During this period we had the chance to record several local and regional earthquakes and compare velocity magnitude produced by earthquakes and local construction works.

8. References

- [1] -GEObit, C100 seismic sensor user manual



Monitoring the earth 

www.geobit-instruments.com, www.geobit.gr

[2] -GEObit, SRi32S digitizer/recorder user manual

[3] -GEOshock user manual