GeoWatch

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GeoSIG

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Keynote: Some Examples for Instrumentation of Structures

Scope:

In this issue of the GeoWatch, we will give some examples for the instrumentation of structures with different purposes. GeoSIG instruments can be deployed on any civil engineering structure such as bridges, dams, nuclear power plants, railroads, roofs, tunnels, etc. to monitor different dynamic, static or transient cases.

Roof Monitoring: *Congress Centre*, Lucerne, CH

Introduction

Roof Safety emerged as a major issue in the Northern European Countries especially in the winter of 2006. Several large roofs have either collapsed or were partially or severely damaged under harsh winter conditions and heavy snow resulting in loss of lives and property.

The main objective of structural design is that a structure is safe under the design actions and that it shall experience inelastic deformations before failure, if the design loads are greatly exceeded. Brittle failure shall be avoided and the safety of the users shall be guaranteed even under extreme conditions. It appears that that in the case of the roofs, which could not withstand the heavy snow loads were either underdesigned for snow, the snow loads have exceeded the design values or the strength of the structural members has deteriorated etc.

GeoSIG measuring solutions cover a wide variety of systems that can serve the monitoring of structures and/or the critical structural components like large roofs. Such a roof monitoring system can typically provide real-time monitoring of the behaviour and response of the roof under actual loads and generate alarms in case a threshold value is exceeded. The monitored behaviour can be static, dynamic as well as permanent or transient in nature. If an alarm is released then the owner/operator of the structure has to perform a series of predefined activities in order to ensure a safe state of the structure.

The Congress Centre of Lucerne (KKL) Roof Monitoring Project is a good example of this application.

The KKL is located on the shore of Lake Lucerne, and is a result of an architectural design competition carried out in 1989-1990 among 67 different teams, which was won by the French star architect Jean Nouvel. The design works started in 1992 and the designer and contractor received the European Structural Steel Design Award in 1999, while the construction was completed in 2000. The KKL has a very busy cultural and social events program hosting tens of thousands of visitors every year.

Figure 1. Congress Centre, Lucerne, Winter 2006. (Dr. Martin Wieland)

The most outstanding feature of the KKL is its rectangular roof of 112.7 m x 107.2 m, with very large cantilevering portions of 36.1 m and 26.6 m in the north and the east directions, respectively. The maximum overhang is about 44.8 m in the diagonal direction at the northeast corner. The roof is almost flat and it consists of a statically indeterminate grillage structure made of steel beams with a grid of 5.4 m x 5.4 m. Due to its immense dimensions, the large wind effects and intensive public usage, a roof monitoring system was installed, for which GeoSIG Ltd. was selected.*

The Roof Monitoring System*

The roof monitoring system consists of the following instruments (Figure 2):

- 9 strain gauges for the measurement of the stresses in the flanges of the main steel girders,
- 2 vertical accelerometers to measure the vertical accelerations at the northeast corner and the central part of the northern edge of the roof,
- 1 thermometer to measure air temperature, and
- 1 anemometer mounted on a mast on the roof to measure the wind speed and wind direction.

The monitoring system has been recording measurements continuously since early September 1998. The stresses and accelerations are measured 50 times every second.

Long Term Monitoring

At the beginning, the measurements made by the monitoring system were processed every day. Since the daily records required handling and storage of a huge amount of data and the wind-induced stresses in the roof girders were observed to be quite small, the preparation of the daily records was discontinued after October 1999. Since then, the long-term monitoring data have been kept only in the form of monthly records.

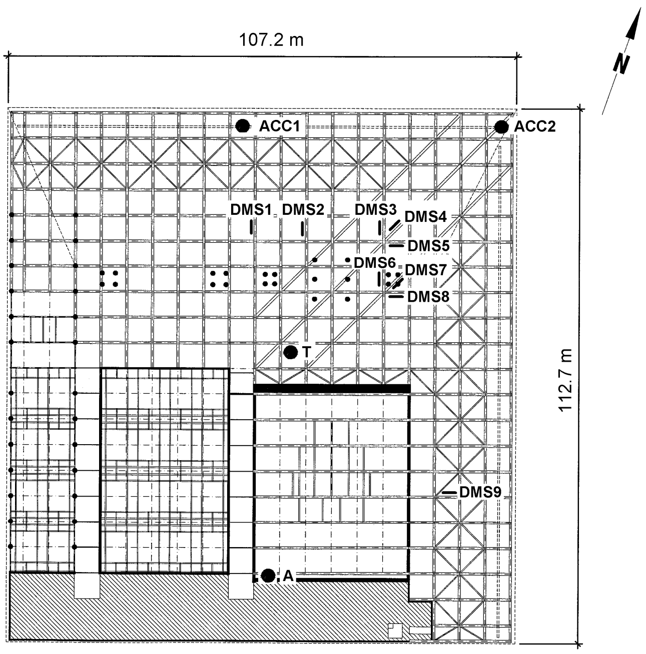

Figure 2. Locations of the strain gauges (DMS), accelerometers (ACC), thermometer (T) and anemometer (A).

The monitoring system computes and stores the maximum and minimum values of the measured quantities every 2 hours and plots them every month (see also Figure 3). In addition to the time histories of the measured quantities, the monthly records include cumulative histograms of stress ranges determined by the rainflow counting method.

Event Records

Whenever the wind speed exceeds 80 km/h, a detailed record of an event is stored for duration of 300 s. An event is also registered when the accelerations and the stresses exceed specified limiting values.

During an event recording, the power spectra of the vertical accelerations are also computed. This helps to identify the natural frequencies of the roof. The lowest natural frequency of the roof determined in this way is 1.27 Hz, which is quite close to the computed value of 1.37 Hz. Any significant reduction of the measured natural frequencies would indicate a possible structural problem. No such change has been noticed up to now.

Alarm System

The monitoring system also generates an alarm signal when the wind speed exceeds 100 km/h, or the maximum vertical acceleration exceeds 0.1 g, or the maximum stress change is larger than 100 N/mm2. Depending on the nature of the alarm, various preventive measures are taken.

At the end of December 1999, the storm Lothar swept across Europe causing strong winds and widespread destruction mainly to forests. This roof monitoring system has provided valuable data about the full-scale behaviour and the safety of the roof structure during strong winds. More detailed analysis of this event and the performance of the Monitoring System can be found under the web site of Poyry Energy AG, Zurich, CH.

* Adopted from: *Dr. M. Wieland & Dr. S. Malla, Dynamic behaviour of roof of Congress Centre of Lucerne during Lothar storm of December 1999, Proc. EURODYN 2002, Munich, Germany, September 2 – 5, 2002*

Monitoring During Heavy snowfall of March 2006

Starting on 3 March 2006 a heavy snowfall affected the Central and eastern parts of Switzerland. The snowfall lasted for up to 2 days and the snow remained on the ground for about a week. During this period, significant snow accumulation has also occurred on the KKL roof (Figure 1).

The GeoSIG roof monitoring system has successfully archived this significant event within the continuous recording, revealing the reliability and detailed behaviour of the roof. The plot in Figure 3 summarises a 12 day period including the snow storm. The effects of this event can be seen clearly between the 4th and 10th days on the plot. While several conclusions can be made after investigating this plot, the most prominent ones can be listed as follows:

- The roof structure has an elastic response under the superimposed (and significant) snow loads,
- A monitoring system is an invaluable tool for even well designed structures, in order to understand the behaviour under actual real life conditions.

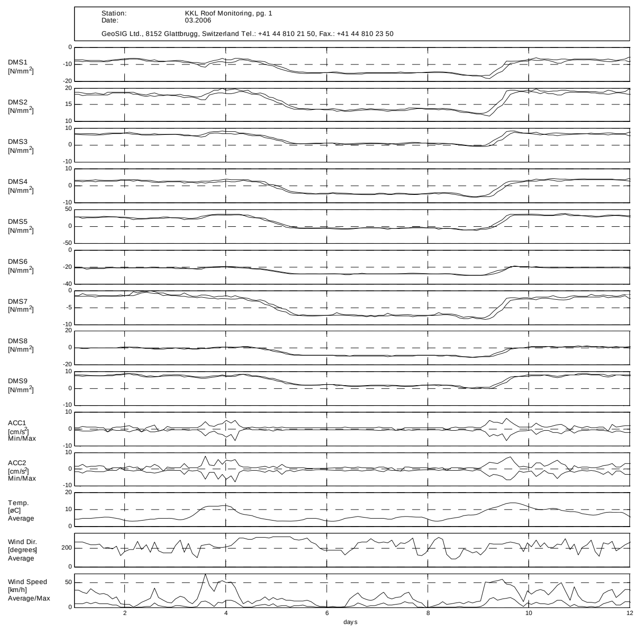

Figure 3. A 12 Day overview of the recorded sensors

Penstock Monitoring: Schwanden, CH

In coordination with Poyry Energy AG, GeoSIG Ltd. has provided a penstock monitoring system to SN Energie AG in Schwanden.The maximum pressure in the penstock is 110 bar. A monitoring system has been provided for a curved section of the penstock.

The monitoring system continuously records the signals of 22 strain gauges distributed along the penstock and its circumference, the system voltage, ambient and steel temperature as well as the water pressure in the penstock (Figure 4).

The different channels, SMS alarms to mobile phones and alarms in control room of the power plant are configured and controlled via GeoDAS. If the monitoring system detects an AC, DC or strain gauge related exceedance of the threshold values, an SMS with parametric information about the event is sent to different people. Alarm generating thresholds for the strain gauges are set at three levels to identify how serious the situation is as well as to provide some lag time (until the system reaches the next higher alarm level) in case a potentially dangerous situation develops. Specific action plans have been defined for each alarm level. The monitoring system has been in successful operation since November 2004.

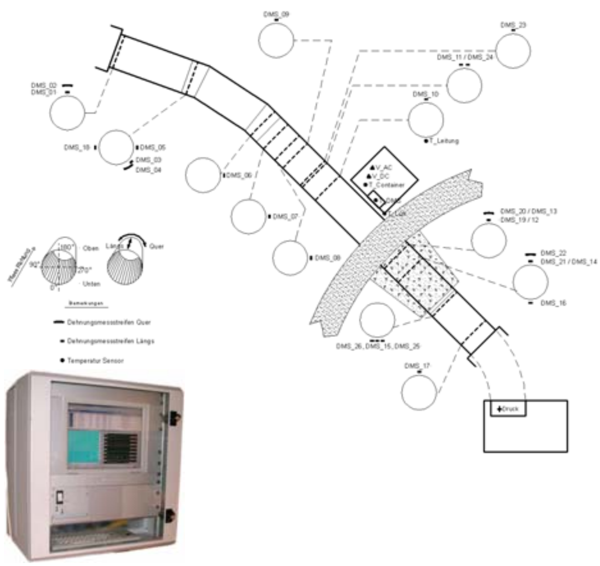

Figure 4. Schematic Sensor Locations and CR-5 in operation

CR-5 PC Based Multi-channel Central Recording and Monitoring System

CR-5 is a PC based central recording system with up to 120 dynamic and more than 500 static channels. Packed inside a rugged industrial packaged housing, CR-5 offers 16 Bit resolution per dynamic channel with real-time display, sampling rates from 50 to 1000 SPS, GPS synchronized recording, large capacity data storage options, alarm relays, SMS / Email messenger, more than 24 hours power autonomy, galvanic isolation and over voltage protection, and a complete on-line surveillance, diagnostics, self checking and reporting system.

The CR-5 was developed out of years of experience in monitoring civil engineering structures such as dams, nuclear power plants, pipelines, tunnels, bridges, highways, railroads as well as historical, commercial or residential structures all over the world. This modern multi-channel central recording and monitoring system provides engineers with a valuable tool to fully understand and analyze the dynamics of structures in the operating environment. With a CR-5 system the dynamics affecting the structure including but not limited to acceleration, velocity, displacement, temperature, current, wind speed, wind direction, stress and pressure may be monitored and recorded.

Dynamic channel sample rates of 50, 100, 200, 500 and 1000 SPS are provided. The system is based on synchronised multi-channel A/D converters. After hardware anti-aliasing filtering the signals are digitised using the over-sampling and decimation techniques resulting in superior data quality.

The heart of the CR-5 software is GeoDAS, a proven data logger and data analysis package developed by GeoSIG Ltd.

GeoDAS is frequently used in large seismic networks. GeoDAS integrated into the CR-5 central recording monitoring system provides a richly configured set of user-friendly capabilities, displays and analytical tools running under Windows XP operating system. Optionally, SEISLOG can also be used.

Figure 5. CR-5 general view

In addition to the near real-time display of the dynamic channels the system provides static data like mean, max, min, and peak values. The CR-5 monitors the real-time data generated by each of the sensors attached to the system and compares the measured data to five fully independent alarm trigger criteria. The ring buffer size, the post event time, trigger thresholds and relay alarm on/off times may be selected by the user.

A comprehensive surveillance, diagnostics reporting system through alarm relays, SMS and Email is provided.

Third Nuclear Power Plant Instrumentation in Switzerland

Gösgen Nuclear Power Plant is the third NPP in Switzerland instrumented with GeoSIG Seismic Monitoring System (SMS).

The factory acceptance tests of the system were carried out on 20 April 2006 and the installation will be completed by the end of June 2006.

GeoSIG Exhibited at the SSA 2006, 100th Anniversary Earthquake Conference

Almost 4000 delegates from around the world attended in the commemoration of the 1906 San Francisco Earthquake, the 100th Anniversary Earthquake Conference, announced as the largest earthquake conference ever held. The conference, hold in April 2006 at Moscone Center, joined the annual meetings of the Earthquake Engineering Research Institute (EERI), Seismology Society of America (SSA), and California Office of Emergency Services (CA OES).

GeoSIG attended the exhibition during the conference (Figure 6). Besides several interesting new contacts it was a pleasure to get in personal contact with existing and potential clients. GeoSIG would like to thank the organiser of the conference for the perfectly organised conference and exhibition.

Figure 6. GeoSIG exhibition boot.

Nuclear Logistics Inc. Cover Marketing Activities in the North American Nuclear Market

To be more effective in the North American Nuclear Market, GeoSIG reorganises the marketing activities for the Nuclear Market in North America (USA, Canada, Mexico).

Effective by 12th May 2006 Nuclear Logistics Inc. (http://www.nuclearlogistics.com/) acts on an exclusive basis as a value added reseller of the GeoSIG equipment to the North American Nuclear Industry.

Reminder: 1st European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland, September 2006

The First European Conference on Earthquake Engineering and Seismology will take place in Geneva, Switzerland in September 3-8, 2006.

The European Association of Earthquake Engineering (EAEE) and the European Seismological Commission (ESC) have long traditions of periodic conferences: The European Conference on Earthquake Engineering (ECEE) takes place every four years, and the General Assembly of the ESC every second year, respectively. In 2006, the EAEE and the ESC will join the 13th ECEE and the 30th ESC General Assembly to hold for the first time in common the First European Conference on Earthquake Engineering and Seismology (1st ECEES). *(For more information, please refer to http://www.ecees.org/)*

GeoSIG Ltd. will participate in the conference within the exhibition area. We hope you visit us there.

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