# GeoWatch

December 2006, Issue 31

GeoSIG

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## Keynote:

### Scope:

We have enhanced our line of sensors with a new and cost effective accelerometer, AC-43, which we introduce in detail in this issue. The well known GeoSIG seismic switch series AS-1x has recently become a highly desirable high-end unit for especially industrial and residential premises and we have dedicated a brief section on the options available for this sophisticated and versatile instrument. In addition we present an interesting article about undesirable floor vibration analysis conducted together with our business affiliate rci dynamics using an IA-1. If you had missed our stand in the past ECEES '06 in Geneva, you can still have a look via the short overview given in this issue. Another new line of GeoSIG products, the GSK-166 uniaxial shaking table will be in focus in one of the next issues. Please contact us if you need more information, earlier.

## New!!! AC-43 MEMS based Triaxial Accelerometer

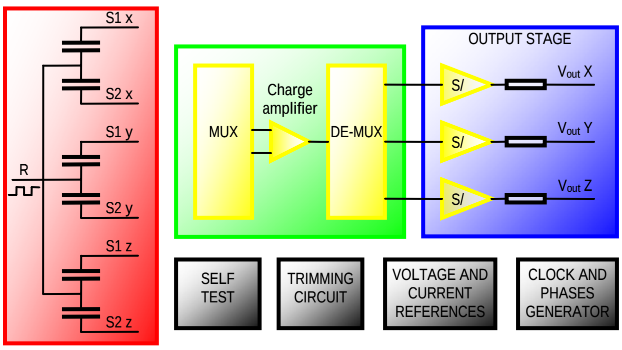
The AC-43 sensor package is a triaxial accelerometer designed for urban and industrial applications regarding strong motion earthquake survey and vibration monitoring as well as alarm and switch systems.

All these applications require rugged sensors with minimum maintenance and a simple method for periodic testing.

The AC-43 accelerometer is based on the modern MEMS (Micro Electro-Mechanical Systems) technology, consisting of sensing cells assembled in a way that optimizes their performances. This combined with the state of the art proprietary circuit design yields this cost effective and reliable accelerometer.

MEMS cells include linear accelerometer sensing elements which measure the capacitance variation in response to any movement or inclination and a factory trimmed interface chip that converts the capacitance variations into analog or digital signal proportional to the motion.

The AC-43 is typically housed in the standard GeoSIG sealed cast aluminium housing with dimensions of 193 x 112 x 94 mm. The housing also incorporates a single bolt mount with three levelling screws. Stainless steel packaging options are available.



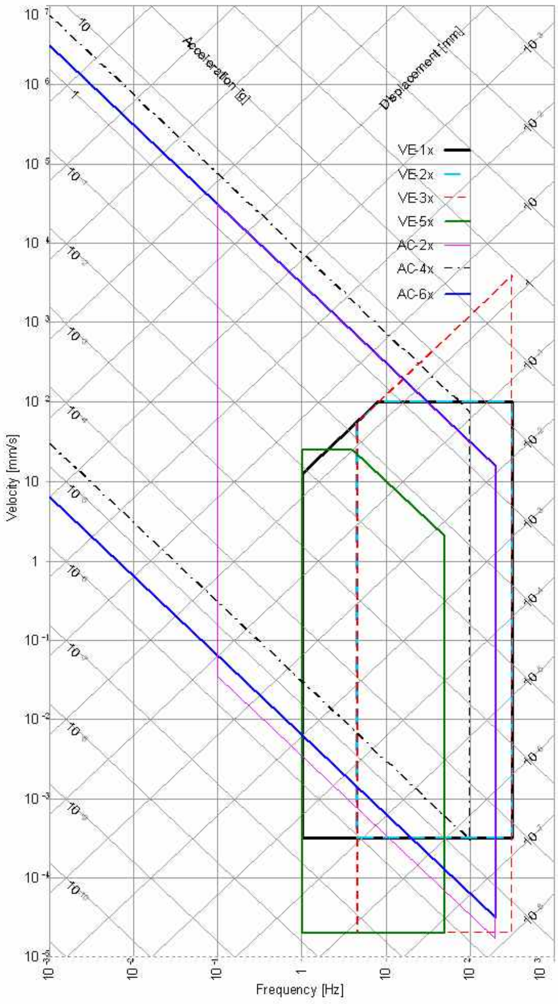




*Figure 1. AC-4x in comparison with other GeoSIG sensors*

The DC response allows the sensor to be easily repaired, tilt tested or recalibrated in the field. With the help of the TEST LINE the AC-43 accelerometer can be completely tested assuring proper operation.

Available sensor axis and packaging configurations are shown in the following table.

*Table 1. AC-4x axis and packaging options*

| | Triaxial | Biaxial | Uniaxial | Axes | Alignment** |
|---|---|---|---|---|---|
| AC-43 or AC-43i*: | ■ | | | X – Y – Z | H – H – V |
| AC-42-H or AC-42-Hi*: | | ■ | | X – Y | H – H |
| AC-42-V or AC-42-Vi*: | | ■ | | X (or Y) – Z | H – V |
| AC-41-H or AC-41-Hi*: | | | ■ | X (or Y) | H |
| AC-41-V or AC-41-Vi*: | | | ■ | Z | V |

* i : Internal sensor  ** H: Horizontal, V: Vertical

The AC-4x accelerometer is directly compatible with the GeoSIG recorders. It is also designed to be mounting internally in standard GeoSIG recorders. In such case, the AC-4x provides the lowest power consumption and weight.

*Figure 2. AC-4x as external sensor*

## AS-1x Series Seismic Switch

GeoSIG AS-1x Seismic Switches ranging at 12, 16 and 18 bit versions, provide a complete and high-end blast / earthquake / seismic monitoring and alarm system including accelerometer sensor, digital threshold detection circuitry for two independent switch levels, output relays, and backup battery powered by an AC charger. The AS-1x is housed in a rugged, industrial rated cast aluminium enclosure with connections for AC power and seismic switch relay contacts.

The AS-1x is ideally suited for accurate monitoring of impulses or vibrations along with relay contact closure at two different acceleration levels for warning and/or alarm functions. Factory “Pre-set” Alarm Low/High set-points include 0.15 g / 0.30 g and 40 gal / 100 gal. The AS-1x also provides user programmable set-points over a 0.002 g to 2.0 g range of acceleration.

Key features of the AS-1x include simple installation and low maintenance operation. Compensation for non-level mounting (within ± 5º) is provided by the AS-1x’s sophisticated digital electronics therefore special levelling is not required.

Automatic system self-checks are performed every 30 days (or at user selected times) and a service warning indicator is illuminated if unscheduled maintenance is needed. A service warning relay output is also available as an option.

The AS-1x’s internal rechargeable battery provides 48 hours of backup power if the 90-260 volt AC power is lost. An AC indicator is provided to check that active charging power is present. The AS-1x enclosure provides for sealed cable entry or conduit fittings.


The AS-1x Service Port provides complete in-field testing using GeoSIG’s supplied GeoDAS Software including battery levels, analog and digital circuit checks and switch/relay tests.

Advanced 2 out of 3 relay logic is available for complementing the deployment of AS-1x especially in industrial shutdown operations as well as for emergency management such as in high-rise buildings, where reliability with confirmation is required.

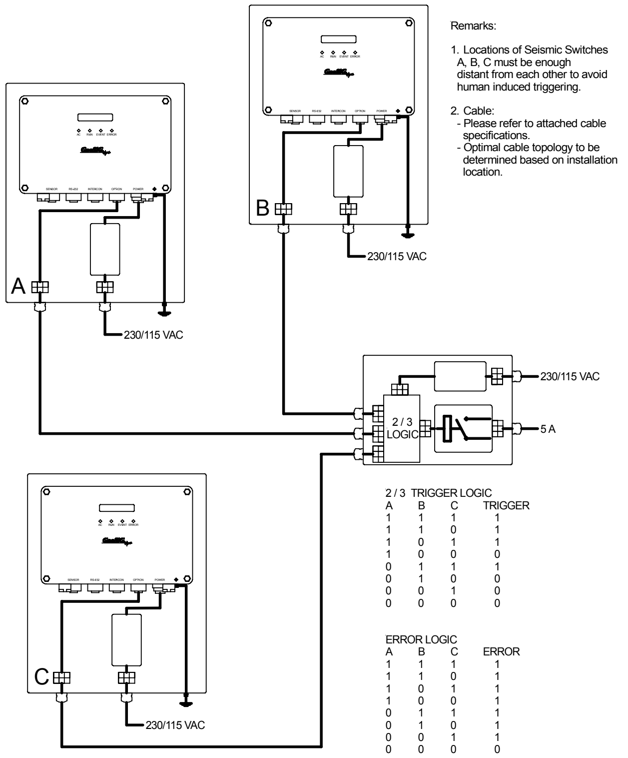



*Figure 3. A sample deployment option for 2 out of 3 logic*

## Office Floor Vibrations: Modal Parameter Identification and Vibration Monitoring

On behalf of the European Association for Structural Dynamics (EASD), the Sixth European Conference on Structural Dynamics EURODYN’05 was held in Paris on 5th September 2005. Dr. Reto Cantieni (CEO of rci dynamics) and Dr. Talhan Biro (Project & Marketing Manager of GeoSIG) had published a paper on “Modal Parameter Identification and Vibration Monitoring”. Here we would like to give a summary of that paper.

## Abstract:

Several people working on the 2nd floor of an office building complained about disturbing floor vibrations. The building consists of five floors with a largest free-span dimension of ~7 m on the diagonal. In the contrary to the other floors, the 2nd floor slab has no floor-to-ceiling secondary walls neither beneath nor on top of the slab.

To identify the problem and to achieve a reasonable basis to evaluate a solution, two kinds of tests were performed:

- System identification of the floors (determination of natural frequencies, mode shapes and damping coefficients),
- Monitoring of the 2nd floor vibrations for two months.

Processing of these data yielded that no other source of the vibrations could be identified than people walking on the floor. Rating of the measured vibrations according to ISO 2631 yielded that during working hours, the vibration levels ranging from 0.47...1.45 mm/s were up to 3.6 times higher than the "satisfactory" 0.4 mm/s. At the moment, discussions are ongoing to find an optimum solution for the problem.


## Modal Parameter Identification

*Ambient Excitation*

To determine the structures' modal parameters, a modified Ambient Vibration Technique (AVT) was used. In the contrary to large civil engineering structures where the usual ambient sources of excitation like wind, traffic or seismic micro-tremors are inducing nice structural vibrations, problems may arise when investigating relatively small floors.

To identify the dynamic parameters of such a structure, experience has shown that it is a good idea to artificially increase the level of structural vibrations during the "AVT" investigation. Moving on the floor and dropping a 5 kg medical ball from a height of roughly 1 m at irregular intervals of one to four seconds has proven to be a very efficient means of excitation for concrete floors exhibiting dimensions of several meters. (Figure 4)

The advantages of this procedure are three-fold:

- the vibration level induced in this way is definitely larger than any "noise" vibration induced by any "dynamic" piece of equipment in the building (including the vibrations induced by the ball thrower's walking),
- the impulses generated by the ball (obviously; according to experience) have an optimum duration and the frequency band of interest is excited very nicely,
- and the risk of the excitation sitting in a node of a structural natural vibration is zero. The latter is a very important advantage versus any kind of Forced Vibration Testing (FVT), where the point of excitation usually has to be kept constant due to practical reasons.

*Figure 4. The medical ball used to excite the slabs and one of the accelerometers used to measure the slab response.*

*Response Measurements*

Piezo-electric sensors PCB 393B31 with a sensitivity of 10 V/g were used to measure the floor vibrations (Figure 4). The measurement point grid consisted of three vertical reference points and 35 roving vertical measurement points. The latter were covered with five roving sensors in seven setups.

The sampling rate was s = 100 Hz and the length of the time windows 5 minutes.

During one weekend, the floors No. 1, 2 & 3 were tested in this way in the absence of anybody in the building except the test crew. The 4th floor was tested in a minimum way only. Here, the first couple of natural frequencies were established without determining mode shapes and damping coefficients.

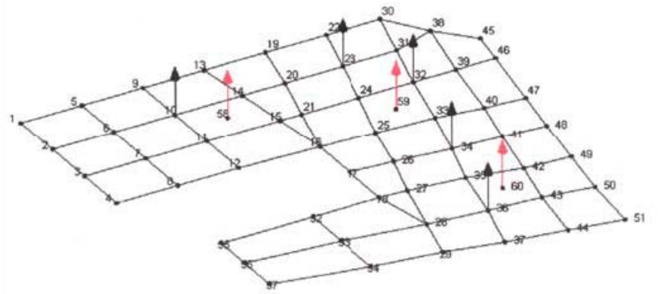


*Figure 5. The measurement point grid. The red arrows indicate the position of the three reference sensors (located outside the grid lines), the black arrows the five roving sensors of setup 1.*

*Signal Processing and Results*

EFDD (Enhanced Frequency Domain Decomposition) and SSI (Stochastic Subspace Identification) methods as offered from the ARTeMIS Extractor software package were used to identify the modal parameters. Although being based on completely different algorithms, both methods yielded almost identical results. The largest differences were found for the damping values. However, most of these differences are quite small when compared with the results of tests on other structures.

The fundamental natural frequencies of the floors were: 2nd Floor: 7.4 Hz; 1st, 3rd and 4th Floors: 11.5-12 Hz. The shapes of the 1st, 2nd and 3rd modes as well as the natural frequency [$f_n$] and damping [$\xi$] (in percentage of critical damping) of the 2nd floor are given in the Figures below.

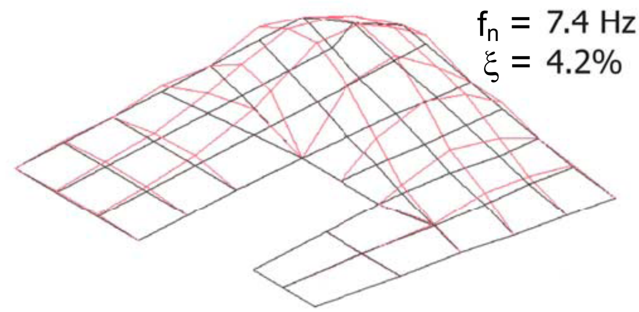



*Figure 6. 1st Mode of 2nd Floor.*

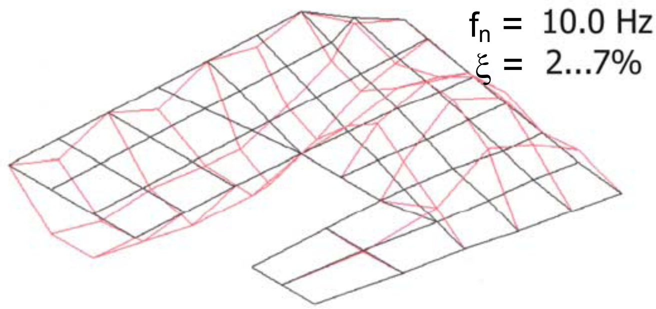



*Figure 7. 2nd Mode of 2nd Floor.*

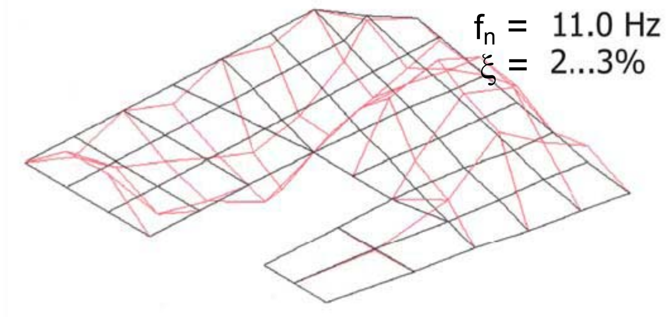



*Figure 8. 3rd Mode of 2nd Floor.*

**Vibration Monitoring**

*Instrumentation, Data Acquisition*

To monitor the vibration intensity and to identify the source of the vibrations, a triaxial velocity sensor was subsequently mounted in a critical point of the 2nd floor slab. The vibrations were monitored for two months using a GeoSIG internet-accelerograph IA-1. This allowed on-line checking of the vibrations and downloading of the data on an external server on a daily basis. The instrument originally has internally mounted accelerometers, but a modified version was deployed with an external GSV-310 velocity sensor for this monitoring project. (Figure 9)

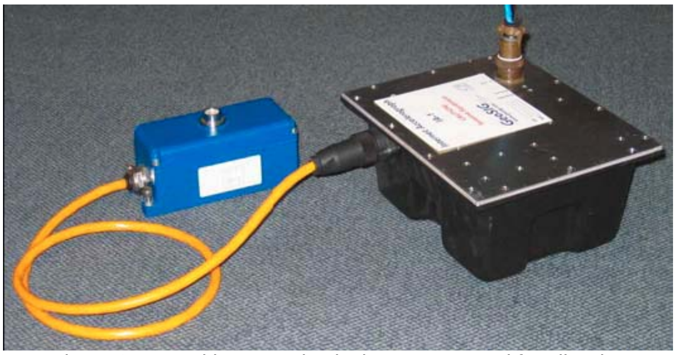


*Figure 9. IA-1 with external velocity sensor, used for vibration monitoring.*

The three signals were continuously sampled with a rate s=100 Hz and stored every five minutes in a file on the IA-1 local disk. This disk is large enough to store the signals collected for 2.5 days.

Every day, the 288 data files were transferred via internet to a remote server. This internet connection also allowed checking each of the 5-minute-files immediately after it had been saved to the local disk from any given point in the world having internet access (and the necessary security permissions to reach to the IA-1). Application of this procedure was facilitated very much through the fact that the IA-1 could be hooked-up to the local intranet available in the office building under investigation.

*Signal processing*

Using the GeoDAS software package, for each 5-minute time window a number of characteristic values could be determined within seconds. These values cover several types of maximum and averaged values as well as the dominant frequency.

*Results*

Figure 10 to Figure 12 show the peak values of all 288 5-minute-time windows of the vectorial velocity as a function of time for a 24-hours monitoring time. Diagrams of this type were calculated on a daily basis and were used to get a first insight into the behaviour of the floor under investigation. The behaviour as shown in these figures can be called "typical" and covers almost all of the 64 days of undisturbed 24-hours monitoring. These "typical" diagrams, identically scaled on the ordinate, include a normal working day (Figure 10), a typical Saturday (Figure 11) and a typical Sunday (Figure 12).

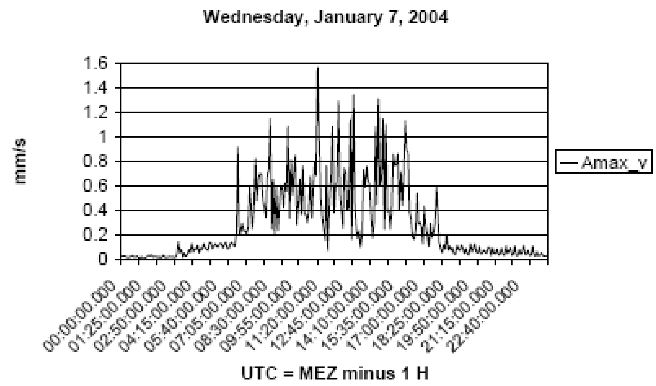



*Figure 10. Floor vibrations for a typical normal working day.*

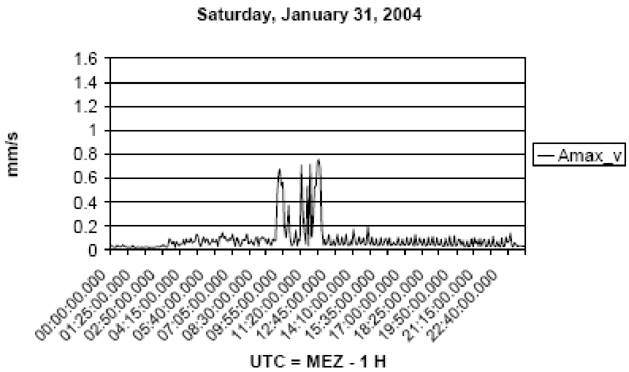



*Figure 11. Floor vibrations for a typical Saturday.*

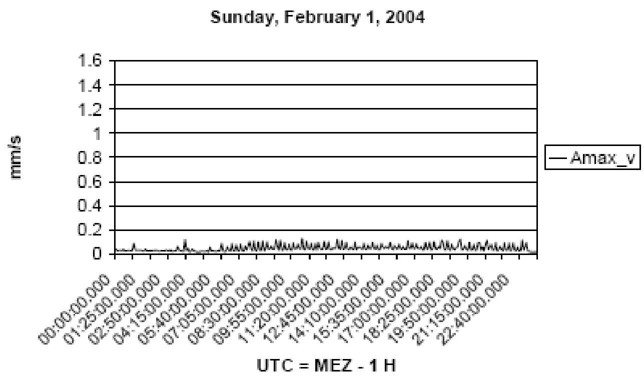



*Figure 12. Floor vibrations for a typical Sunday.*

Therefore, as a first result of the monitoring tests, it could be noted that no other source could be identified than people walking on the floor.

**Discussion of the Floors' Dynamic Characteristics**

As can be taken from Bachmann & Ammann (1987) and Bachmann ed. (1995), problems with concrete floor vibrations excited through walking people can be expected if f<7.5 Hz.

This easily explains the fact that problems were encountered with the 2nd floor but not with the other floors.

Two remarks can be added here.

- The stiffening action of floor-to-ceiling walls located on top of a concrete floor is obviously much more important than their mass effect. There is no other explanation for the 3rd floor fundamental natural frequency being a factor of 1.6 higher than the one of the 2nd floor (with exhibiting an almost identical mode shape!);

- It is interesting to note that the fundamental mode of the "clean" 2nd floor exhibits higher damping values than the ones of the 1st and 3rd floors. Both, the 1st and 2nd floors have no floor-to-ceiling walls, but they have several partitioning "cardboard" walls with a height of some 0.3 m less than the room height. As a matter of speculation (and may be considering the shape of the respective fundamental mode) these partitioning walls contribute better to the damping capacity of the 2nd floor than to the one of the 1st floor (the 3rd has no "cardboard" partitioning walls).

**Rating of the 2nd Floor Vibration Levels**

*Perceptibility*

According to Bachmann & Ammann (1989), perceptibility of human beings to vibration is proportional to acceleration for f=1-10 Hz and proportional to velocity for f=10-100 Hz. Staying with velocity, the threshold of perceptibility is 0.16 mm/s, v>0.64 mm/s means "just perceptible", v>2.0 mm/s means "clearly perceptible", and v>6.4 mm/s means "disturbing / unpleasant". Transforming the measured velocities into acceleration based on a dominating frequency f=7.4 Hz and applying the respective thresholds given yields the same results as for the velocity values:

- the vibration level measured without presence of people is close to the threshold of perceptibility,
- the vibration level measured for normal working conditions is mainly between the levels "just perceptible" and "clearly perceptible".

*Acceptability*

The German standard DIN 4150-2 (1999) which is widely used in Europe can be applied to vibrations in residential buildings only.

The measured vibrations were therefore rated according to ISO 2631-1 (1997) and ISO 2631-2 (1989). This rating is based on measured RMS-values of acceleration or velocity. Processing the signals using the GeoDAS software package allowed plotting similar graphics as shown in the Figure 10 to Figure 12 for RMS- instead of peak values (Figure 13).

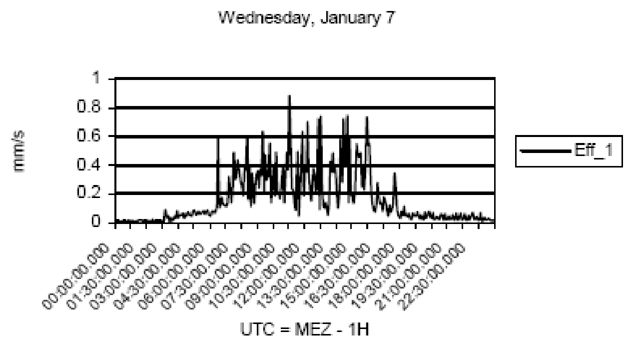



*Figure 13. Floor vibrations for a typical normal working day.*

The values for the two cases of interest are:

- normal working day: $v_{RMS}$=0.47-1.45 mm/s, 0.8 mm/s on the average,
- nobody present: $v_{RMS}$=0.07-0.17 mm/s, 0.11 mm/s on the average.

Three parameters have to be taken into account when applying ISO 2631.

- the frequency weighting curve (Figure 14),
- the base curve (Figure 15), and
- the multiplication factor.


*Figure 14. Frequency weighting curves as given in ISO 2631-1 (1997). Wk (solid line) applies for vertical movement.*

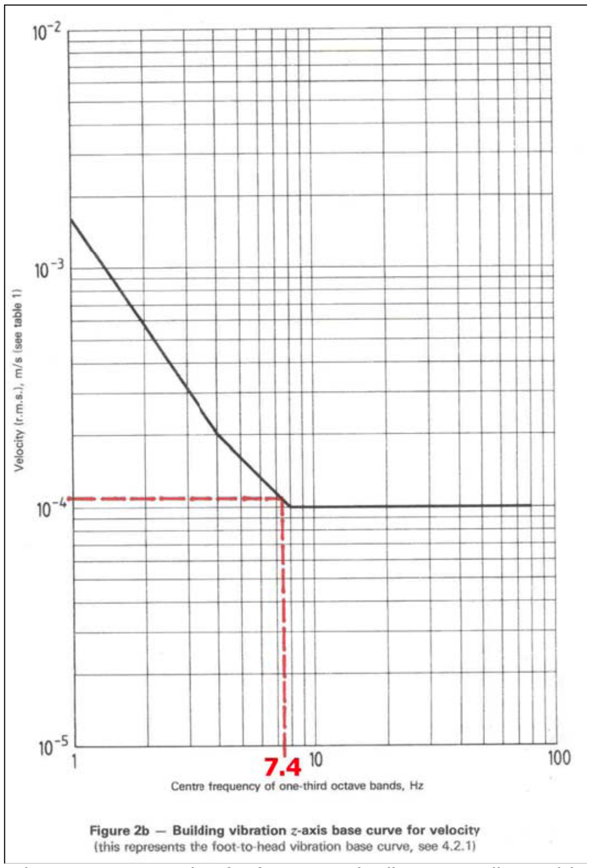



*Figure 15. Base value for f = 7.4 Hz (ordinate's scaling: m/s).*

For office buildings, "continuous or intermittent vibration", "day" and "night", Table 2 of ISO 2631-2 (1989) gives a multiplication factor 4.

During working hours, the vibration levels are up to 3.6 times higher than the "satisfactory" 0.4 mm/s according to ISO 2631. The vibration level valid for the state "nobody present in the building" is well below the "satisfactory" level according to ISO 2631.

**Conclusion**

As the primary result, the investigation discussed here shows that a lower frequency limit f=7.5 Hz for the fundamental natural frequency of concrete slabs in office buildings is not conservative.

Furthermore, the investigation showed that the presence of "non-load-carrying", secondary floor-to-ceiling walls on top of a slab significantly influences the slab's dynamic characteristics. The stiffening effect of such walls seems to be much larger than their mass effect.

Finally: The presence of lightweight partitioning walls with a height of less than the room height seems to (positively) influence the damping capacity of the slab.

*REFERENCES*

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*Bachmann, H., ed., 1995. Vibration Problems in Structures – Practical Guidelines. Birkhäuser Verlag, Basel, Boston, Berlin.*

*DIN 4150-2 1999. Erschütterungen im Bauwesen – Teil 2: Einwirkungen auf Menschen in Gebäuden. Deutsches Institut für Normung, Berlin.*

*ISO 2631 – 1 1997. Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General Requirements. International Organization for Standardization, Geneva.*

*ISO 2631 – 2 1989. Evaluation of human exposure to whole-body vibration – Part 2: Continuous and shock-induced vibration in buildings. International Organization for Standardization, Geneva.*

## 1st ECEES was held in Geneva, Switzerland, September 2006

The 1st European Conference on Earthquake Engineering and Seismology was held 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 joined 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. participated in the conference within the exhibition area.where we had displayed a number of our latest products such as a custom-built GNC-CR with a portable casing as well as our innovative uniaxial linear shaking table GSK-166. For further information on these products, please contact us.

With this opportunity we would like to thank to the organizing committee of the conference, for this flawlessly planned and steered event, especially the two Co-Chairman's Dr. Martin Koller (Swiss Society for Earthquake Engineering and Structural Dynamics, SGEB and Résonance Ingénieurs-Conseils SA, Geneva) and Prof. Dr. Domenico Giardini (Swiss Seismological Service, SED, ETH, Zurich)

## NPP Gösgen Seismic Instrumentation is Successfully Commissioned by GeoSIG

The share of Nuclear Power Plants in the overall electricity production in Switzerland is approximately 40 percent. Such important energy production assets require also lucid and up to date maintenance and operation procedures and facilities.

Seismic instrumentation of most of the active Nuclear Power Plants in Switzerland have been upgraded to the state of the art technology as of June 2006. The upgrades were carried out by GeoSIG within the framework issued by the Swiss Nuclear Authority, generally based on the regulations set forth by U.S. Nuclear Regulatory Commission.

The last step was the installation and commissioning the NPP Gösgen Instrumentation, which was performed recently in perfect coordination with the NPP management and staff.

## GeoSIG Supports Academic Research and Development

GeoSIG, by its tradition, supports young scientists in their endeavours to achieve the best available education and experience throughout their studies.

We have a strong affiliation with a number of scientific organisations in Switzerland to be able to actively contribute to their teaching programs and related projects.

*Prof. Dr. Werner Witz*

Past academic year, we have participated in the Diploma Thesis of two students from the University of Applied Sciences Northwestern Switzerland, under the supervision of Prof. Dr. Werner Witz of Technical Institute of Microelectronics.



*This professional bulletin has been prepared by GeoSIG Ltd.*

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**We would like to take this opportunity to announce that our annual winter holiday will be from the 23rd of December 2006 until the 7th of January 2007,**

**And Wish You a Happy and Prosperous New Year**