Issue 12 - September 2003

newsletter

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SAMCO NEWS

Structural Assessment Monitoring and Control | Issue 12 | November 2003

contents

Published by VCE.

3rd European Conference on Structural Control

Call for Papers

3ECSC

3rd European Conference on Structural Control

The call for papers is still running, as the deadline for the paper submission has been postponed to December 31, 2003!

You are kindly invited to submit a short, two pages abstract of your contribution for the purpose of review.

The proceedings of the conference are planned to be published in the prestigious book series of the Technical University Vienna "Schriftenreihe der Technischen Universität Wien" (editor-in-chief: R. Viertl).

This conference aims at fostering scientific interactions among the vast community of researchers contributing to structural control in a broad sense, and at strengthening the European research and professional community of structural control. Cross-fertilization between the different scientific disciplines and interactions with professional engineers will be encouraged.

Enjoy together with the scientific program, the conference dinner at Vienna City Hall and the charm of Vienna.

The conference venue – the Technical University Vienna – is located in the heart of Vienna, not far from the most famous cultural and historical attractions of the city.

For more details please refer to the conference website: www.samco.org/3ecsc

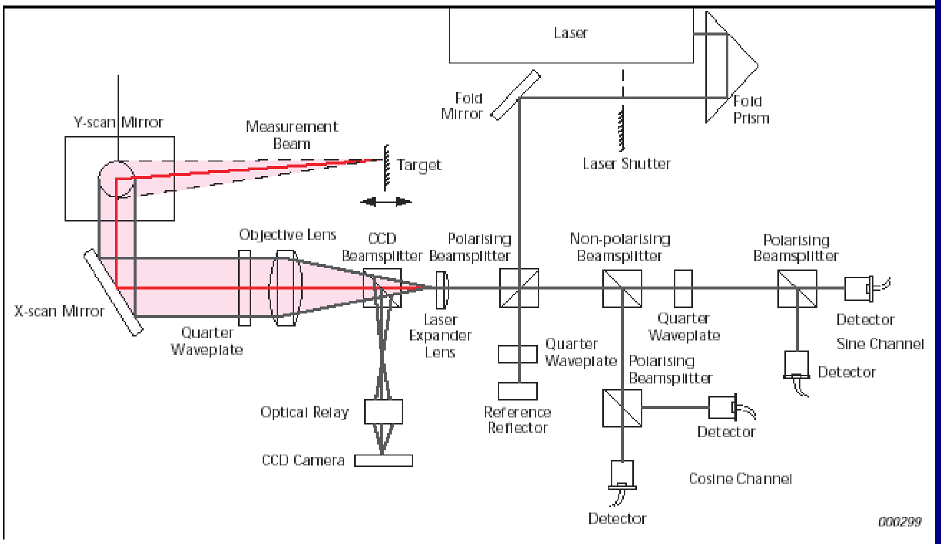



News from the Profession & Practice

Vibration Testing / Laser Scanning: Application for the Protection of Cultural Heritage

▲ Figure 1: Fresco " Historical Innsbruck "

Figure 2: optical layout of the used Laser - Doppler - Vibrometer ▼



Due to the construction of a new railway station in Innsbruck, Austria, two frescos from the Austrian artist Max Weiler had to be removed, restored and prepared for the re-installation in the new building. A laser scanning investigation was carried out by VCE, in co-operation with Brueel&Kjaer, to ckeck the current condition of the frescos and to evaluate the result of the restauration.

For transportation and restauration of the frescos (7x12m) “Historical Innsbruck” (Figure1) and “Modern Innsbruck” were attached on a carrier system. In the course of the restoration numerous cavities between the fresco and the plaster had to be filled by injections. One of the challenges of the restoration was that the pictures had to be brought into an upright position. Because of the extraordinary size of the pictures this can cause mechanical claims, that can endanger the durable success of the restoration. The aim pf the dynamic vibration test should prove that:

- a continuous group between the basic finery layers and the fresco is guaranteed by the restauration,
- by the restoration the frescos can set upright heedlessly without new damage to the frescos,
- the current condition of the frescos is documented. Because of this a comparision basis for the installed condition of the frescos is given.

Defects were recognized by volatility in the modeshapes during checking the dynamic of the frescos.

The oscillation answers on the surface and a reference signal for the phase purchase is measured. The reference signal was taken up with a reference sensor mounted at the steel frame of the frescos. OmniPower sound source with a power amplifier was used as exiter. This sound source uses a cluster of 12 loudspeakers in a dodecahedral configuration that radiates sound evently with a spherical distribution. All twelve speakers are connected in a series-parallel network to ensure both in-phase operation and an impedance that matches the power amplifier. With this components the system was induced with a noise of 1 kHz. The measurement of the surface took place contactlessly via a Scanning Laser Doppler Vibrometer (SLDV) which was mounted on a scaffold above the frescos. The principle of operation of the SLDV is based on the Doppler effect: in same way in which the sound reflected or emitted from an object in motion undergoes a frequency shift, also a beam of coherent light reflected from a surface in motion is subjected to a frequency variation. In the latter case the percentage of variation is very small, 1 part in 10^8, can be detected accurately only resorting to optical interferometer with the aid of electronic systems. The laser sensor is based on a Michelson interferometer. A optical layout of the instrument used is shown in Figure 2. The laser beam is divided towards the surface of the object which is vibrating. One part of the divided beam is the measurement Beam. The other part is the reference beam. Since the surface is in motion, the difference in the optical path between the two beams changes in continuation producing an interference that can be destructive or constructive. This signal can be seen as an amplitude modulated signal.

A complete cycle of modulation corresponds to a movement of the surface equal to $\lambda/2=3.16*10^{-7}$ metres, that is half wavelength (λ) of the Helium-Neon laser used like as source of monochromatic light. Therefore the modulation frequency (Fd) correspondent to the surface speed v is given by Fd=2v/ λ. We see that Fd is the Doppler frequency associated to the reflection from a surface moving at speed v and when frequency demodulated the signal will give an analogous voltage proportional to v itself.

Commercial systems measure up to 10m/s with frequency bands in the order of 200 kHz. Instrument resolution is in the order of some tens of nanometres of surface displacement, so that this instrument is capable of detecting events not to be seen by any other equipment. On a treated surface, the measure distance catches up the 200 metres, while on a generic surface the range remains in the order of 10 metres. The power of the employed Helium-Neon laser is <1mW so that it is not necessary to adopt any safety measure, neither for the operator nor for eventual spectators.

The beam get recombined inside the SLDV and then it is shared between two independent detection channels in such a way, that the interferometric path difference presented to the other channel. This configuration results in a 90° phase shift between the signals from the two channels.

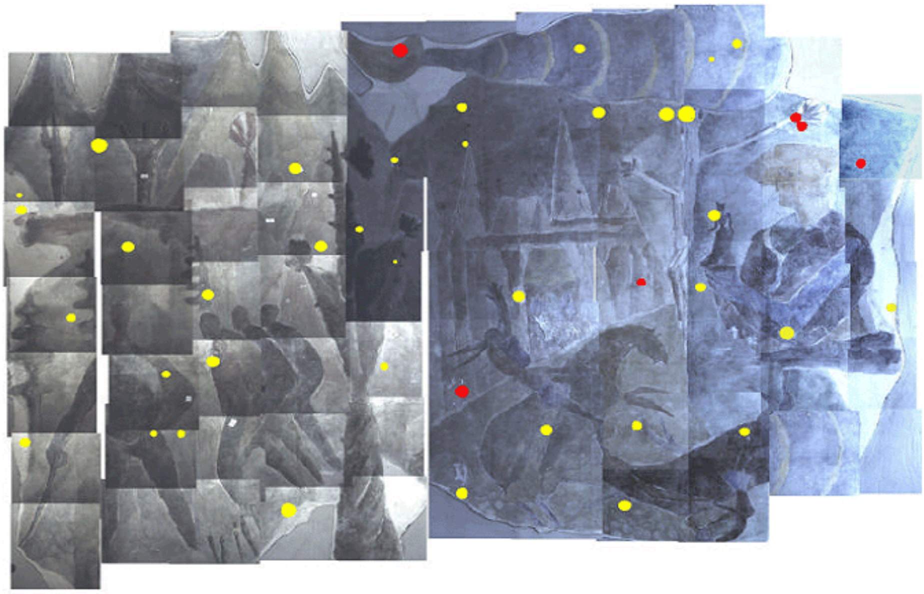
The direction of the surface motion can thus be determined by looking at which signal leads the other in phase.

Current models are completely managed by a computer and data are recorded in several digital formats, recognized by most common software packages. Animations of structural resonances can be viewed immediately after a scan is completed. These “operating deflected shapes” (ODS) are usually enough to identify which parts of a structure require reinforcement or damping, or which parts of the structure are generating noise. ODS is also very accurate approximation of the actual mode shape if the mode is not closely coupled to adjacent modes. Researchers needing more than ODS analysis can quickly export ASCII data directly to modal analysis programmes in Universal File Format. Finally all SLDV systems are portable and truly tested in order to operate also in non-optimal environmental conditions.

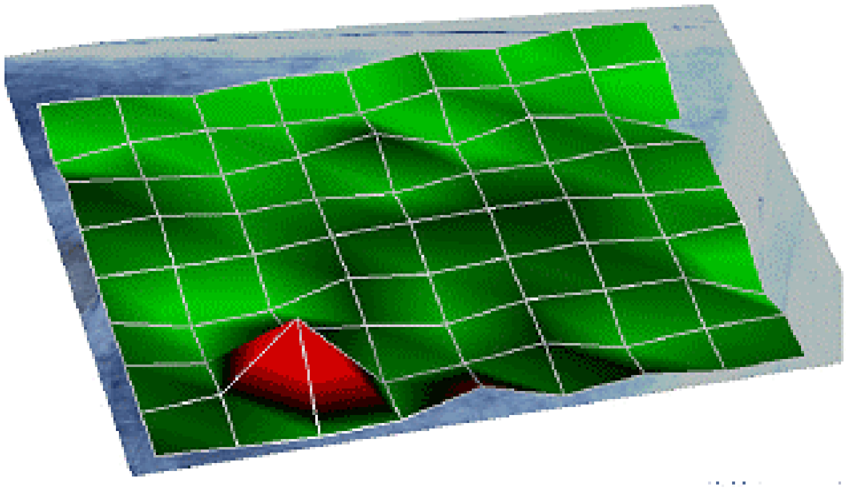
Because of the limited opening angle of the laser beam of 25° and a laser head assembly height of only approximately 2 meters only areas with a dimension of approximately one square meter could become scanned by one installation.

For measuring the howl fresco we had to make 74 installations per fresco. For each Installation between 81 and 100 points were measured. So the distance between the measuring point was between 95 and 100 mm. The situation of the measuring fields is shown in Figure 5 at the fresco “Modern Innsbruck”.

Disturbing influences can affect the result of an optical vibration measurement lastingly. Therefore attention had to be paid to dropouts. The laservibrometrie is based on reflected scattered light and is thus strongly surface-dependently. The partially dropouts that are resulting from this problem must be registered and these measuring point have to be seized a second time. The available compound of fresco and basismaterials (honeycomb plate, Epoxo-foam, lime mortar, glass fabric, synthetic resin, and so on) forms a socillationable system with typical resonant frequencies within the range 300 and 500 Hz .



▲ Figure 5: Defects at “ Historic Innsbruck



▲ Figure 4: Defect in Field 1 at 365 Hz

By defects (cavities, seperations, cracks) a loss of stiffness arises, which leads to low resonant frequencies within the range of 150-350 Hz, depending upon kind and size of the defect. Figure 4 shows a defect in Field 1 at Fresco “Modern Innsbruck” at 365 Hz

The destignation defect refers to the dynamic characteristics of the structures. Thus errors which affect the vibration-response can be recognized.

As result of the investigation the found defects were tabular listed under indication of the coordinates and the size and kind of the damage were indicated. Additionally the seized damage was marked in a summar screen.

Figure 5 shows this at the Fresco „Modern Innsbruck“. The red Points underline the places on the fresco who has clearly gone into action. This places let expect clearly mechanical defects. The yellow Points underline the places on the fresco who let expect mechanical defects that are not critical now.

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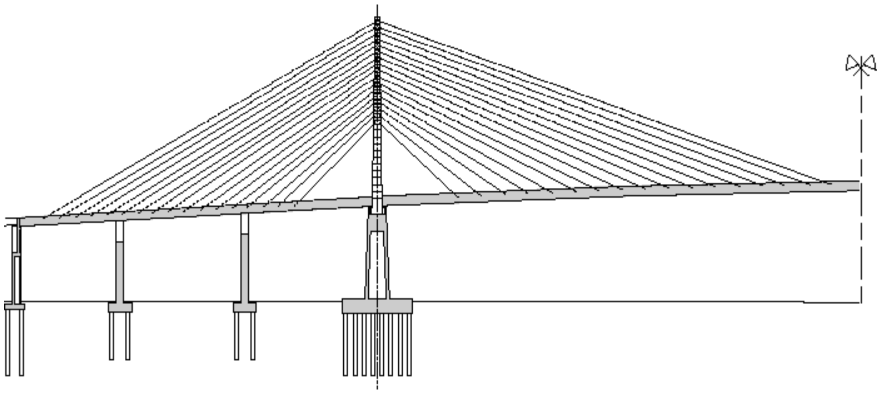
Non Destructive Inspection of Stay cables: A Reference Project and New Developments

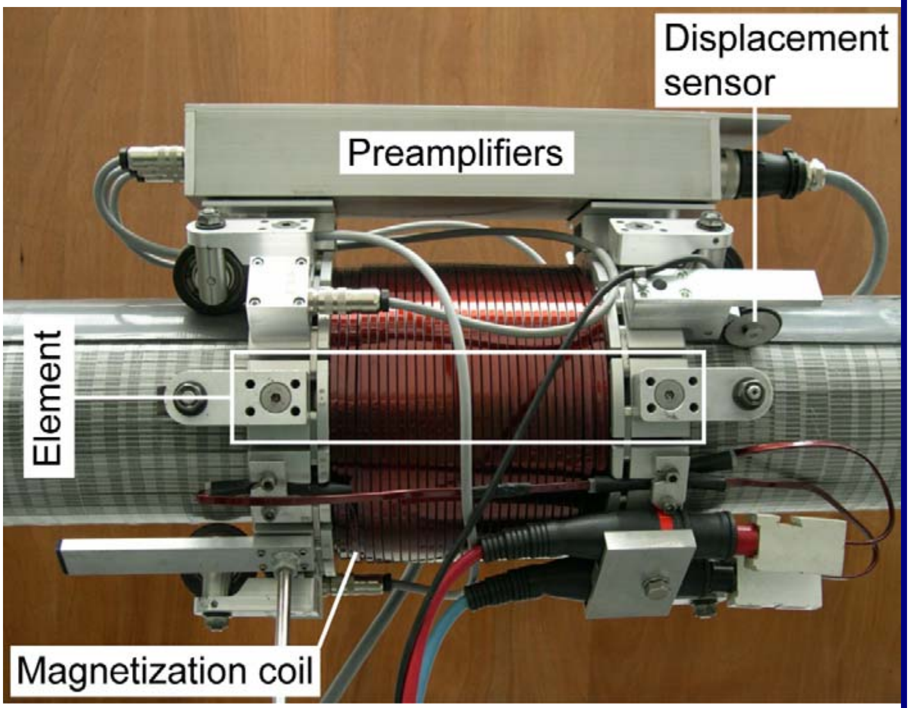
Since the introduction of stay cable technology around the beginning of the 20th century, the spans covered by cable-stayed bridges, and subsequently the size of the cables installed on such objects, have increased noticeably. Many of these structures have now reached an age where the assessment of their state is becoming necessary.

At present the choice of non-destructive methods to assess the condition of the free length of steel cables is very limited. Among such methods, radiography and the measurement of the stiffness of the cables with dynamic methods shall be mentioned. In many cases, where the diameter of the stay cables exceeds 100 mm, radiography implies the use of very strong radiation sources that make this method less practical, in spite of its reliability. Other methods for the non-destructive assessment of the cables, such as ultrasonic or visual inspection have limited application for practical reasons.

Magnetic Flux Leakage (MFL) methods represent a viable approach to the inspection of the free length of stay cables with a large diameter.



▲ Figure 1: longitudinal section of RAMA IX Bridge



▲ Figure 2: EMPA's magnetization and MFL detection device

RAMA IX Bridge in Bangkok, Thailand

The Rama IX is a single plane cable stayed bridge with steel box girder and orthotropic deck and steel pylons. It is comprised of a main span (450 m) and two back spans (61.2m+57.6m+46.8m). The bridge carries 6 lanes of traffic. A total of 68 locked coil cables (121mm≤Ø≤168mm) are divided in 4 groups of 17 (1 group on each back span and 2 groups on the main span of the bridge).

Purpose of the Inspection

The non destructive inspection of the free length of the cables was carried out as part of a general inspection of the structure. Its purpose was to find and locate wire ruptures in the free length of the cables. The assessment of the conditions of the cables after approximately 10 years from installation was specifically recommended by the supplier. The results of the inspection were evaluated by the bridge owner and its consultants together with the other findings of the general inspection.

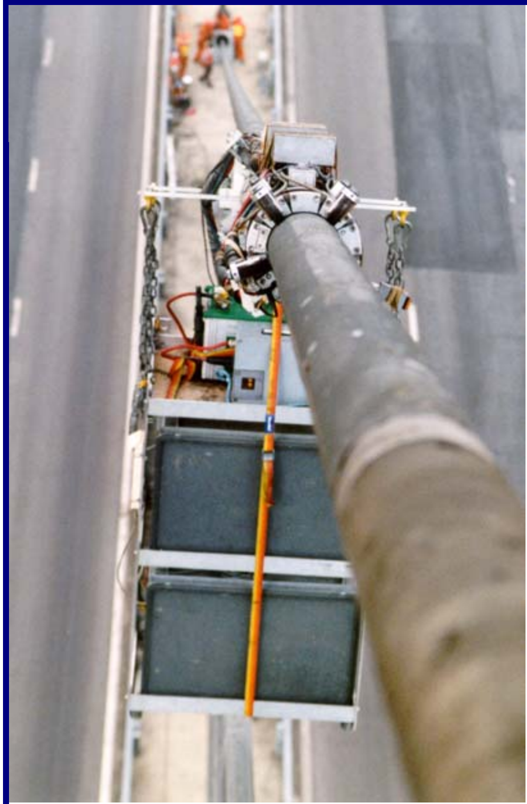
Description of the Equipment

The physical principles underlying the MFL method are well known and understood: The presence of an air-filled flaw in a magnetized steel part causes a local perturbation of the magnetic flux field, due to the local discontinuity of the magnetic properties (permeability) of the materials. Under appropriate conditions, such perturbation can be detected at the surface of the sample. The equipment used for the inspection was developed at EMPA based on the know-how and experience gathered over 30 years of non destructive inspection of aerial tramways in Switzerland.

The NDE unit has two main functions:

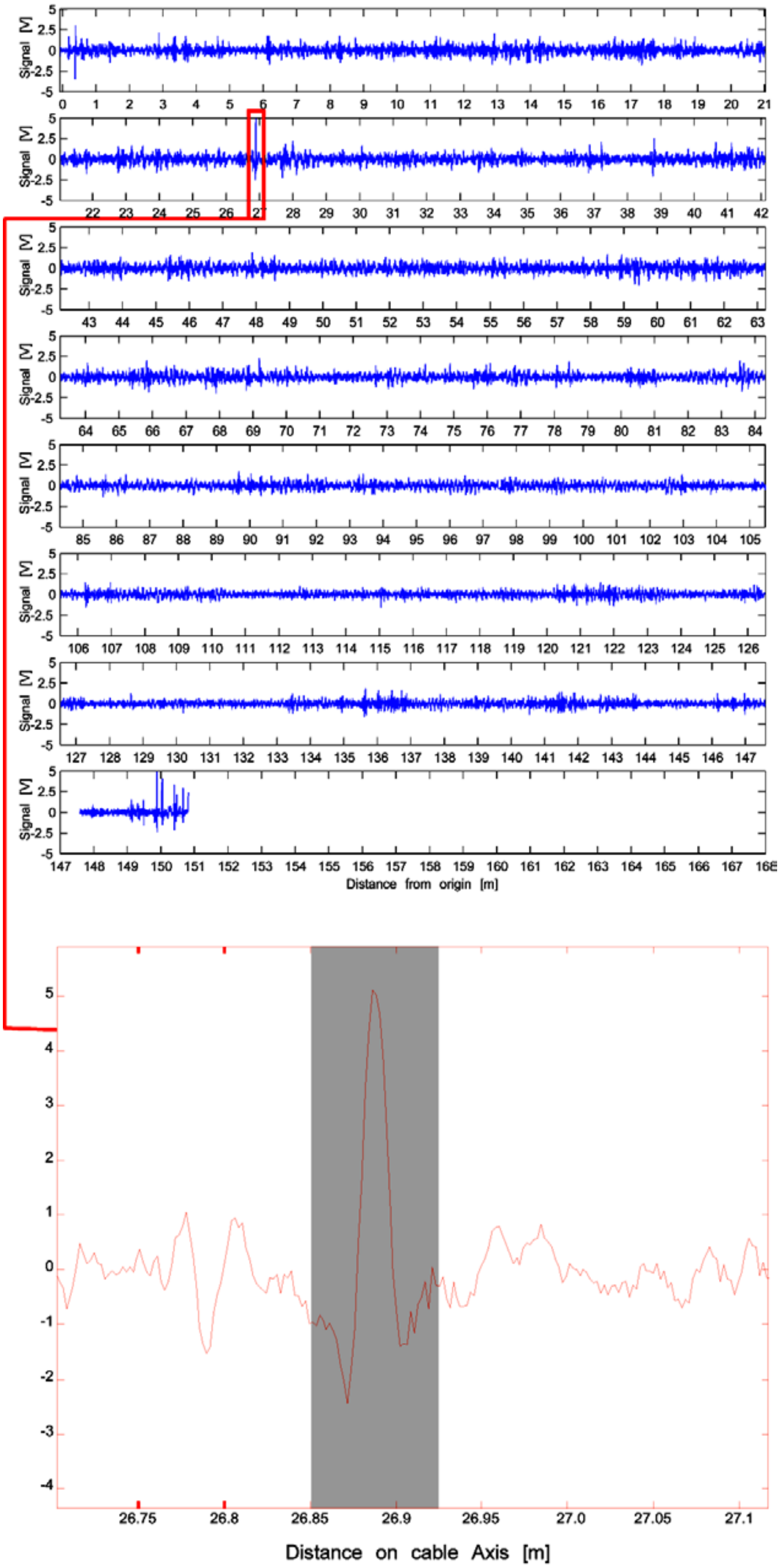
- Generation of the necessary magnetic field to magnetize the sample
- Detection of the MFL field on the surface of the sample

The first task is performed by circulating a strong DC current (approximately 100 A) through a magnetization coil wound around the cable (See figure 2). The detection of the MFL is performed by an array of pick up coils (not shown) located between the magnetization coil and the surface of the cable along its circumference.



◄ Figure 3: NDE unit moving along a stay cable as seen from the pylon

Figure 4: Typical MFL signal for the whole length of a 150 m long cable and detailed representation of the signal originating from a flaw. ▼



The system is completed by a PC based data acquisition unit, a displacement sensor and signal conditioning devices. For the inspection of the cables, the complete battery powered system was pulled at a speed of approximately 0.5 m/s along the stay cables by means of an electrical winch connected through a thin steel wire rope, as shown in figure 3. A scan of a cable was completed in 5 to 15 minutes, depending on the length, and yielded a dense two dimensional MFL intensity map on the surface of the cable.

The first information about the presence of flaws in a cable could be obtained from the sum of the signals originating from the sensors. A typical signal recorded on a 150m long cable is shown in Figure 4.

New developments: 3D-Localization

Since the completion of the inspection of the RAMA new data analysis methods for the evaluation of the recorded MFL maps have been developed at EMPA. A method for the 3D localization of flaws is outlined in the following section.

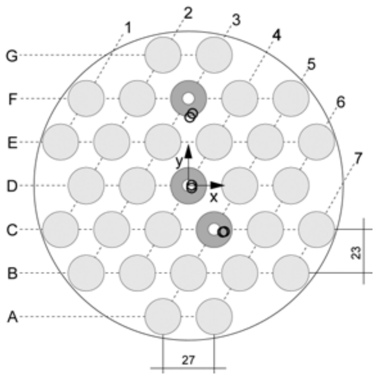
While for locked coil cables and parallel wire bundles the localization of flaws within the cross section of the cable is of limited practical use, this information can be useful for multi-strand systems. One of the potential advantages of multi-strand systems is that it is theoretically possible to exchange individual damaged strands, when needed.

In order to identify the strands that need to be replaced it is necessary to locate the position of existing flaws within the cross-section of the cable. A method based on the use of simple physical and mathematical models describing the shape of the MFL field as a function of size and position of a flaw (see eq. 1) is used for this purpose.

$$(1) \quad \vec{B} = \mu_o \left(\begin{vmatrix} 0 \\ 0 \\ H_a \end{vmatrix} + \frac{\mu_m - \mu_i}{2\mu_m + \mu_i} H_a a^3 \begin{vmatrix} 3r_z r_x / r^5 \\ 3r_z r_y / r^5 \\ (3r_z^2 - r^2)/r^5 \end{vmatrix} \right)$$

Appropriate transformation of (1) and fitting to the measured MFL map yields the coordinates of the position of the detected flaw.

Experiments performed on a 31 strand system in EMPA's laboratories show that the described method is a viable approach to the non destructive identification of damaged strands of a multi-strand system. The calculated defect positions of an artificial wire fracture machined into a strand for test purposes are shown in figure 7, for three different positions.



▲ Figure 7: Cross-section of the cable with actual defect positions (dark grey areas) and calculated positions (black circle).

A technique for the automatic recognition of flaws based on the MFL signal has also been developed and is currently in the validation phase. The next step in the development program will be the application and validation of the data analysis techniques on full scale objects. The general inspection of an older bridge would represent an outstanding opportunity for such a project. EMPA is currently in touch with a number of potential partners for the application of these novel techniques to the inspection of older structures.

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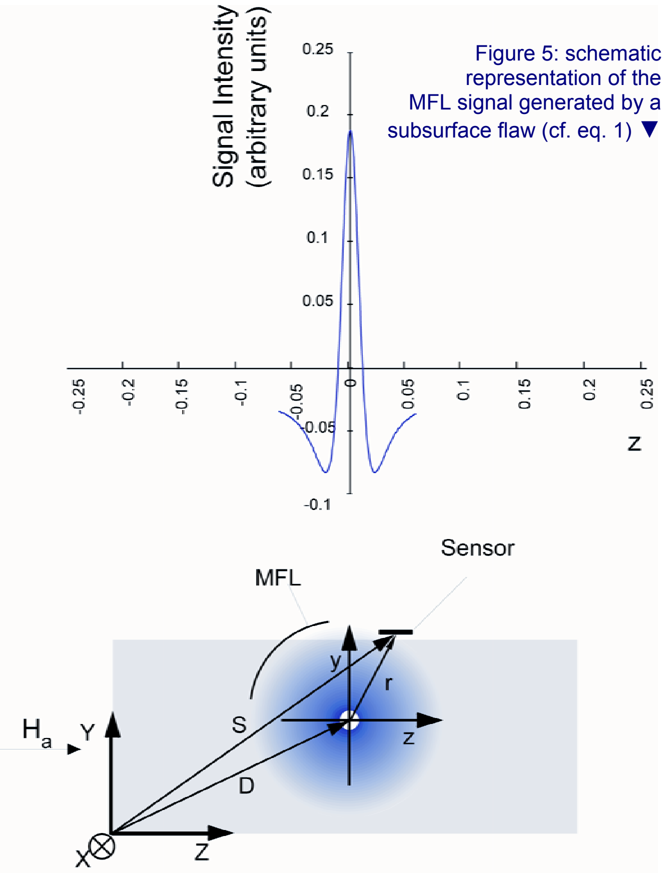


Figure 5: schematic representation of the MFL signal generated by a subsurface flaw (cf. eq. 1) ▼

Figure 6a: Measured MFL signal for a subsurface flaw (31 strand system) ▼

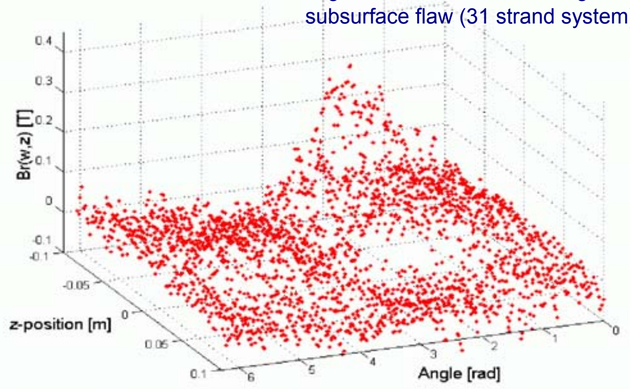
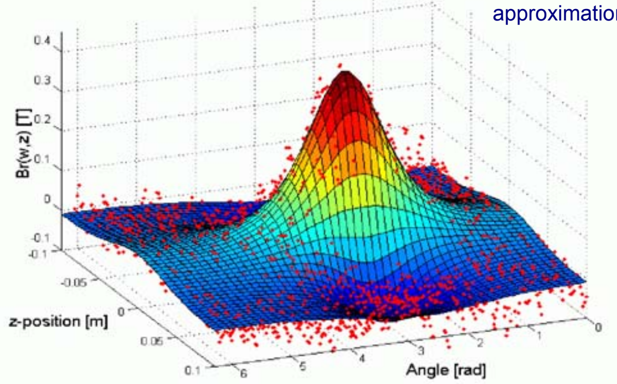


Figure 6b: measured signal from MFL of a subsurface flaw and fitted approximation ▼



Company Profile

Swiss Federal Laboratories for Materials Testing and Research

Our vision is the improvement of safety, comfort and sustainability of engineering structures. In order to reach our goals we apply the long standing experience and knowledge of our team, as well as the outstanding infrastructure to find innovative solutions. We do research and development, knowledge transfer and dissemination, giving services to the industry in the field of statics and dynamics of engineering structures. We focus on the development of the structural health monitoring systems for civil infrastructures, the development of adaptive structures and vibration mitigation systems as well as application of composite materials in construction.

Damage Identification on a Prestressed Concrete Bridge

Vibration based assessment of civil engineering structures has gained much attention in the last years because of its potential application in health monitoring. Many system identification techniques with the focus on damage detection has been developed an validated in laboratory tests showing promising results in detecting, locating and estimating damage in structural components. However, little experience exists in applicability of these techniques on real structures under environmental and operational conditions. To investigate this issue, the Romeo bridge of the Obkirchen highway viaduct in Hergiswil (Switzerland) was progressively damaged.

For further information please contact our homepage www.empa.ch/abt116 - structural dynamics.

Research Project “Controlled Damping Applying Rheological Materials”

The goal of the project “Controlled Damping Applying Rheological Materials” is to damp cable vibrations using semi-active controlled fluid dampers. In order to reach this target, the work can be devided into the following milestones:

- Modeling of the connected system damper-cable (Matlab/Simulink).
- Identification of model parameters by measuring the static and dynamic behavior of the damper and the cable.Model-based controller design.
- Optimization of controller parameters by simulation of the closed loop system (Matlab/Simulink).
- Implementation of the control algorithm at the test set-up computer (LabView Real Time).
- Verification of controller performance at the real system damper-cable

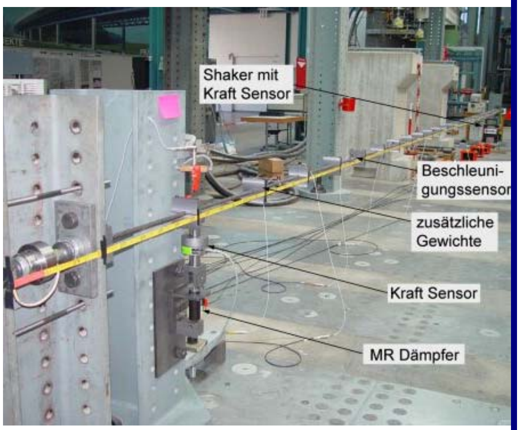
Intelligent Cable-Stayed Bridge

At the end of 2003 a cable-stayed bridge model will be built in our laboratory. The project is motivated among other things by the fact that this bridge will create a link between the often highly simplified laboratory experiments and the more complex, real world structures.

Different research projects of the Structural Engineering Research Laboratory are integrated into the project ‘Intelligent cable-stayed bridge’ as well as some of in- and external partners. Thus the bridge becomes a research laboratory covering the following topics:

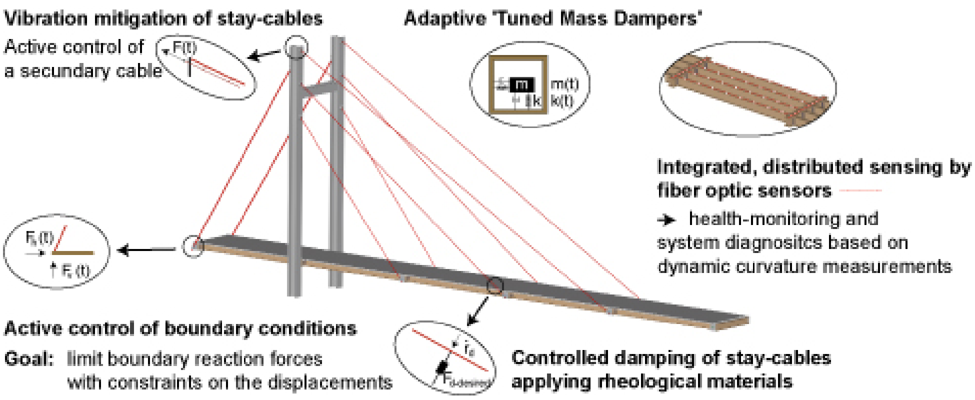
- Structural dynamics: passive, semi-active and active vibration mitigation, health-monitoring, self diagnostics
- Integrated sensing: fiber optic sensors, piezoelectric fiber sensors
- Application of advanced materials as structural elements (glass- and carbon-fiber reinforced polymers)

▲ Figure 1: phase of the progressive damaging of the Romeo Bridge in Hergiswil.



▲ Figure 2: Test setup for MR damping system.

▼ Figure 3: sketch of the planned bridge model



The bridge will be used as demonstration model in training courses to students and interested professionals. Topics like dynamic measuring techniques and modal analysis will be treated

Some subprojects which will be integrated into the 'Intelligent Cable-Stayed Bridge'-Project.

Application of Shape Memory alloys in Construction

The application of Shape Memory Alloys (SMA) has been investigated as prestressing rebars in concrete beams. The shape memory effect is used in order to obtain a controllable prestressed beam.

The investigation showed that the stiffness and the strength of the concrete beam could be controlled by applying different temperatures to the SMA wires.

Features of the testing hall and the strong floor

The Empa testing hall with multiple functionalities is an important corner stone of our testing and research activities. A wide range of test machines are installed in our testing hall.

- Dimension: 12 x 40.8 m, the highest level to be passed by crane is 13.5 m
- Several crane ways are available with loading capacities up to 100 kN.
- 385 anchorages positions

Loading capacity per anchorage point: 2000 kN tension or compression as well as 2000 kN shear.

Standardized steel supports or beams (Mecano like) can be arranged for various test geometries.

A wide range of testing machines for applying forces of up to 20 MN as well as a servo hydraulic with up to 1000 kN tension / compression.

Contact

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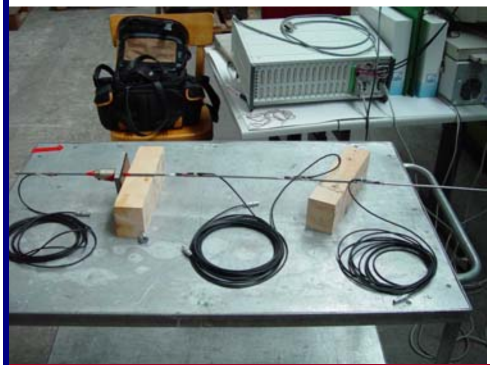
Figure 5: View of EMPA's testing hall ►



▼ Figure 4: Preparation of a SMA wire for characterization.

Announcements

21st International Congress of the Theoretical and Applied Mechanics (ICTAM)

Location: Warsaw, Poland.
Date: August 15-21, 2004.
URL: http://ictam04.ippt.gov.pl

Call for papers

Deadline for the submission is January 9, 2004.

Short Course on Active Vibration Control

Location: Liege, Belgium.
Date: December 8-10, 2003.

Organized by the Active Structures Laboratory (ASL) and the Wallonia Space Logsitics (WSL).

For more information please contact:
AVC@ulb.ac.be

3rd European Conference on Structural Control (3ECSCS)

Location: Vienna, Austria.
Date: July 12-15, 2004.
URL: http://samco.org/3ecsc

Call for papers

Deadline for the submission is December 31, 2003.

Calendar Of Events

March 2004

7-10. Earth & Space 2004, 9th Biennial International Conference on Engineering, Construction and Operations in Challenging Environments; Houston, Texas.
URL: http://www.asce.org/conferences/space04/

8-11. Integrated Intelligent Transport Solutions, *London, UK.*
URL: http://www.iir-conferences.com/iits

April 2004

12.-15. Framcos-5 , Fracture Mechanics of Concrete and Concrete Structures , *Vail, CO, USA.*
URL: http://www.ust.hk/framcos5/

26-28. fib Symposium, Concrete Structures: The Challenge of Creativity, *Avignon, France.*
URL: www.afgc.asso.fr/fib2004/index.html

25-29. Interbuild 2004, The UK's 107th International Building and Construction Exhibition, Birmingham, UK. URL: http://www.unilinkfairs.com

June 2004

2.-4. ICCCBE, Conference on Computing in Civil and Building Engineering; *Weimar, Germany.*
URL: http://www.uni-weimar.de/icccbe/index.html

24-26. 'International Conference on Bridges across the Danube - Bridges in the Danube Bassin; *Novi Sad, Serbia.*
Contact: office@eurogardigroup.co.yu

July 2004

5-7. SEMC 2004 Conference, Second International Conference on Structural Engineering, Mechanics and Computation, *Cape Town, South Africa.*
URL: http://www.ebe.uct.ac.za/~semc2004/

12-15. 3ECSC, 3rd European Conference on Structural Control; *Vienna, Austria.*
URL: http://www.samco.org/3ecsc

August 2004

1-6. World Conference on Earthquake Engineering, Vancouver, Canada.
URL: www.venuewest.com

15.-21. ICTAM, 21st International Congress of Theoretical and Applied Machanics; *Warsaw, Poland.*
URL:http://ictam04.ippt.gov.pl

Imprint

SAMCO News

SAMCO News is a digital newsletter accompanying the SAMCO Network. It is funded by the European Commission in the frame of the GROWTH project SAMCO CTG2-2000-33069. It is an information and communication platform for the participants of SAMCO. It is issued periodically every second month.

SAMCO News is available at http://www.samco.org/news

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The SAMCO Network is funded by the European Commission (http://europa.eu.int) within the *"Fifth European Framework Programme",FP5,* (http://www.cordis.lu/fp5) which covers Research, Technological Development (RTD) and Demonstration activities. FP5 has a multi-theme structure, consisting of Specific Programmes. These Specific Programmes are further divided into Horizontal Programmes and Thematic Programmes. One of these Thematic Programmes is the *"Competitive and Sustainable Growth"* Programme (http://www.cordis.lu/growth/) under which SAMCO is running.

SAMCO is running under the exact term:
CTG2-2000-33069
Shared-cost RTD and Demonstration project, Concerted Action/Thematic Network
Duration: 48 months

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