MEMSCON Newsletter

February 15, 2011

Issue 4

Radio Frequency Identification Tags Linked to on Board Micro-Electro-Mechanical Systems in a Wireless, Remote and Intelligent Monitoring and Assessment System for the Maintenance of CONstructed Facilities

MEMSCON Facts:

- Contract No: 036887
- Project total cost: 4.632.430 €
  EC contribution: 3.814.816 €
- Project Start Date: 1/10/2008
  Duration: 36 Months
- Coordinator:

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Inside this issue:

1st MEMSCON Workshop

The first MEMSCON workshop took place on the 7th October 2010 in Bucharest. The title of this workshop was "**Structural Monitoring and Status-Dependent Maintenance and Repair of Constructed Facilities**" and the goal was to provide a state-of-the-art report on recent research activities, technological utilisation and commercialisation activities in structural monitoring systems and software for the status-dependent maintenance and repair of constructed facilities.

The Balkan region is characterised by high seismicity and is exposed to a high seismic risk. This region was experiencing before the recent financial crisis and will experience again in the near future intensive construction activity because there is a large demand for construction in order to reach the European average. For this reason this workshop took place in Bucharest.

This event attracted more than 60 participants, including academics, sensor developers, European construction companies, owners of constructed facilities, policy makers and sector experts. The agenda included 21 invited presentations, organized in one opening session and three technical sessions. The opening session included welcome addresses from the Workshop organizer, Dr. Dumitru Ulieru (SITEX 45, Romania), from Dr. Angelos Amditis (MEMSCON coordinator), from Dr. Iulia Mihai (Director of Romanian Office for Research and Technology of the Ministry of Education and Research), from Prof. Horea Sandi (Romanian Academy of Technical Sciences) and from Dr Emilio Sever Georgescu (INCERN, Romania). The key note speech was delivered by Prof. Anne Kiremidjian (Stanford University, USA).

The strict connection between technological research and its application to construction industry was remarked by Dr. Jenica Paceagiu (CEPROCIM S.A. Bucharest, Romania), representative of the European Construction Technology Platform (ECTP), and again by Dr. Angeos Amditis, MEMSCON coordinator.

The technical sessions hinged around three major points related to the industrial exploitation of instrumented monitoring in the construction industry:

- Structural Monitoring Systems in Construction
- Monitoring-Based Assessment of Structural Condition and Maintenance/Repair Management in Construction
- Laboratory Evaluation of SHM technologies

The main points addressed in the presentations in this workshop are reported in the rest of this newsletter while the full text of the presentations can be found in this site under 'workshop'.

Grant Agreement No: CP-TP 212004-2
Project funded by : European Commission
Theme 4 - NMP-Nanosciences, Nanotechnologies, Materials and new Production Technologies

Welcome speeches

Workshop Poster

Prof. Horea Sandi (Romanian Academy of Technical Sciences)

Dr. Iulia Mihai (Director of the Romanian Office for Research and Technology, Romanian Ministry of Education, Research and Innovation)

"Initiatives, Policies and Programmes in Support of Research in Romania"

The speaker described the challenges of public funding of the RD&I (Research Development & Innovation) system in Romania and the capacity of this system which is modelled after the EC FP7. The highest percentage of funding (15%) goes to 'Innovative Materials, Processes and Products.'

Prof. Horea Sandi (Romanian Academy of Technical Sciences)

A View on Current Needs of Structural Health Monitoring in Romania

Prof. Horea provided an overview of the structural health monitoring activities in Romania. Moreover, he described the main requirements for the design of monitoring systems for seismic action and structural response (have an integrated network of accelerometers that during an earthquake will provide information concerning the features of the ground motion and structural performance, adopt wireless solutions based on single degree of freedom accelerometers) and offered comments on the strategy for developing monitoring arrays (obtain only the most relevant results with a minimum of expenditures). Finally, Prof. Sandi expressed his interest for future cooperation in the context of the MEMSCON project.

Dr Emil Sever Georgescu (INCERC, Romania)

"Current State of monitoring structures in the seismic areas of Romania"

Dr Georgescu analyzed the seismic setting, earthquake damage and structures at risk in Romania and showed that the seismic areas cover 65% of the territory and include almost 75% of population (over 60% in strong seismic zones). Romania has experienced several earthquake disasters as, for instance, the Vrancea earthquakes of November 10,1940 and March 5,1977.

Keynote Presentation

Prof. Anne S. Kiremidjian (Stanford University)

"Wirelss Structural Health Monitoring and the Civil Infrastructure System: Current State and Future Applications"

Anne Kiremidjian is Professor at the Department of Civil and Environmental Engineering of Stanford University, USA. Since the 1990s, Prof. Kiremidjian's has been working on the design and implementation of wireless sensor networks for structural damage and health monitoring and the development of robust algorithms for structural damage diagnosis that can be embedded in wireless sensing units. In her keynote presentation, she followed the past development and the future perspectives of the technology. Significant developments have taken place over the past 15 years with the first proof of concept of a wireless accelerometer accomplished in 1995. Since them, improvements of the initial system have been continuously taking place leading to a design of a more comprehensive system that include a sensing unit that can accommodate multiple sensors, a wireless communication network that is reconfigurable for different applications, embedded algorithms for controlling the system and a decision support front-end that provides information, diagnoses problems and suggests follow-on actions to technical personnel and managers. According to Prof. Kiremidjian, the development of damage-specific sensors as well as robust damage diagnosis algorithms is seen as imperative for the future adaptation of such systems. Future directions also include multi-scale approach, capability of providing information to designer/builders at different stages of construction and use, and higher level of sophistication of the end-user interface.

Welcome speeches

Monitoring and assessment in the strategic plans of the European construction technology platform

Dr. Jenica Paceagiu (CEPROCIM S.A. Bucharest, Romania)

The speaker presented the ECTP Mission and the priority objectives of the strategic research for 2007-2013 that includes improvement of safety, new integrated processes ICT and high added-value materials.

The MEMSCON Project: Presentation of the concept, objectives and potential impact

Dr. Angelos Amditis (Coordinator of the MEMSCON project, ICCS, National Technical University of Athens, Greece)

"Structural Health Monitoring (SHM) Today - The MEMSCON Project Approach".

Dr. Amditis presented an introduction to Structural Health Monitoring, & Applications, Structural Monitoring Challenges and Technological Barriers & Solutions. At the second part of his presentation the speaker introduced the MEMSCON objectives, tasks and achievements.

The technological project objectives were: to integrate MEMS-based sensors and a RFID tag in a small sized package that will be attached to reinforced concrete buildings to measure acceleration in 3-D or strain in 1-D that will be transmitted to a remote base station using a wireless interface. Additionally, to develop methodologies that based on input from the strain sensors will estimate the differential settlement between foundations and based on Input from the acceleration sensors during an earthquake will estimate the seismic damage. In both of the above cases the type and cost of rehabilitation work will also be estimated.

The partners developed an integrated package for structural assessment and rehabilitation planning under routine operation and seismic forces. The MEMSCON structure, contains domain and system knowledge, a History DB (building records), a sensor data DB, data feature extraction and structural and rehabilitation Models. The monitoring system has a small size compatible with the concrete cover and can operate independently over at least 2 years (even more for the strain sensors) powered by a primary Li-battery and communicate the strain and acceleration sensing data measured to a base station 100-1000m away.

The speaker also underlined the impact of the project in transforming the building rehabilitation sector dominated by SMEs into an advanced knowledge sector and also to enhance the competitiveness of European SMEs in building inspection and rehabilitation. Moreover, MEMSCON will promote the 'Proactive Condition-Based Maintenance' of buildings based on measurements, shifting from construction costs to life cycle costs.

The presentation underlined the European dimension of the project since non-destructive evaluation of the structural condition and safety of in-service buildings on a continuous basis is needed in all EC countries, while in all such countries there are insufficient funds to maintain existing buildings and insufficient number of structural engineers to deal with the issue of life extension of existing buildings. The results are of special interest to the earthquake prone countries of the southern and eastern Europe.

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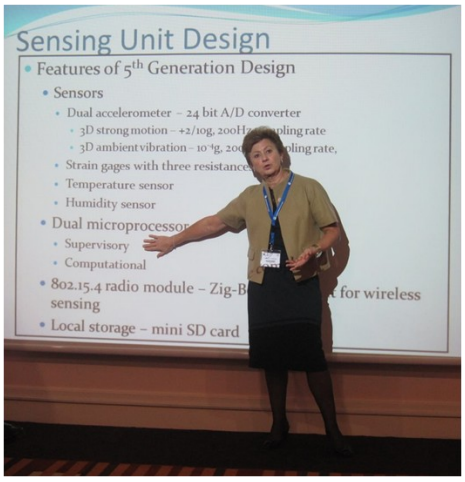

Prof. Anne Kiremidjian (Stanford University)

Technical Sessions

Structural Monitoring Systems in Construction

Dr Sean Neylon (Colibrys S.A., Switzerland)

"MEMS based Seismic and Vibration Sensors in Building & Structural Health Monitoring systems"

Dr Neylon gave an overview of seismic sensing applications that include geosciences, civil protection, civil engineering and in-service structural monitoring, the latter including large buildings, tunnels, bridges and others.

The market supply chain at the lower end includes sensor manufacturers, then hardware integrators and then system integrators that sell to construction companies and government agencies. He suggested that in the addition to the above, an attractive avenue to reach the market can be companies that offer building monitoring and security systems that can be persuaded to include structural monitoring into their systems.

"An attractive avenue to reach the market can be companies that offer building monitoring and security systems that can be persuaded to include structural monitoring into their systems."

The speaker described the 4 classes of accelerometers that exist in the market and the important relevant standards.

He estimated that the market size for class B accelerometers used for structural monitoring is 1 to 10 million $.

He described the latest products of Colibrys for structural monitoring and the roadmap for MEMS accelerometers that includes smaller size, lower power/energy harvesting, improved linearity, extended FS range and integrated wireless.

Dr Markus Krüger (University of Stuttgart, Germany)

"Wireless Structural Health Monitoring - from Research to Reliable Application" Dr Krüger suggested that in order to promote Wireless Sensor Networks (WSNs) in structural monitoring there is a need to develop power efficient hardware and software, inmote processing and automation of analysis. The large amount of complex data derived has to be reduced to only a few values which are sufficient to answer questions of structural adequacy.

The above are implemented in the EC-funded project SMooHS (Smart Monitoring of Historic Structures – www.smoohs.eu) which was described by Dr Krüger.

Dr.Carmen Moldovan (IMT Bucharest, Romania)

"INTEGRAM Project and Use Cases"

Dr Moldova described the INTEGRAMplus project, a Europratice service project providing development platforms for integrated micro-nano technologies and products. The project aims to provide highly integrated Microsystems combining smart Si functionality with polymer platforms in a multi-domain environment. Among the markets that the project expects to address and stimulate included is the multi-domain integration of MEMS and/or electronics.

Mikael Colin (MEMSCAP, S.A., France)

'3-Axis Accelerometer for Building Applications'

Mr Colin described the 3-Axis MEMS accelerometer developed for project MEMSCON. It meets the user specifications for acceleration in the range of 0.01 to 2 g, frequency 0.1 to 10Hz, duration 15 seconds, operating temperature -20 to +50 Celsius, operating humidity 0 to 100 %, vibrations (15g) 1000Hz, shocks 2000g and battery lifetime of 2 years.

The accelerometer has been tested at the structural laboratory at the University of Trento and is part of an integrated package for building monitoring and structural assessment under seismic forces.

Juan Santana (IMEC-NL, Netherlands)

"**3-Axis Accelerometer and Strain Sensor Readout for MEMS- Based Capacitive Sensors**"

The speaker presented a low-power capacitive readout for MEMS-based strain sensors and accelerometers used in project MEMSCON. A novel technique to optimise the trade-off between gain, bandwidth and noise is introduced. The readout can work with both types of sensors in the range of ±2.5g and ±20,000 με. Artefact cancellation such as residual motion is suppressed due to accurate control of the 3dB point in the built-in filter of the architecture. A figure of merit of 4.41×10^{-20} FV(W/Hz) was achieved. The ASIC was developed using a 0.25μm CMOS technology.

MEMSCON Wireless Acceleration Sensor Enclosure

Technical Sessions

Monitoring-based Assessment of Structural condition and Maintenance/ Repair Management in Construction

Dr Dimitris Bairaktaris (DBA Ltd., Greece)

"Monitoring-Based Assessment of the Structural Condition of a Building under Operating Loads and of the Seismic Damage in Reinforced Concrete Buildings"

Dr Bairaktaris explained that in order to assess the structural condition of a building through a network of sensors one needs at least 6 sensors per structural element, or, 1950 sensors for a typical 5 story building.

In MEMSCON the number of required sensors has been dramatically reduced. Thus, in order to assess the structural condition of a reinforced concrete building under differential settlement between foundations only 3 strain sensors were placed at the bottom cross-section of the columns at the ground floor level. In this way, a typical, say, 5 story building, with 25 columns, will need 75 as opposed to 1950 strain sensors. This is possible because instead of aiming at a direct assessment of the internal forces in each member, some critical global parameters of the overall stress condition are being sought. Then, under operating conditions, the internal forces in each structural member as well as their structural adequacy and the differential settlement between foundations are being assessed through a commercially available finite element programme that accepts as input the measured values of the above critical parameters.

To assess seismic damage, in addition to the strain sensors described above, 2 3D accelerometers are placed in every floor and the building basement. They provide 50 measurements per second during an earthquake. Double numerical integration of these measurements yields the corresponding absolute horizontal translations as a function of time. These translations are inputted as imposed displacements in a sequence of non-linear analyses on the finite element space model of the structure (already constructed for the condition assessment based on settlements) by using a commercially available structural analysis programme. From these analyses one can derive the maximum values of the internal forces and curvatures at the critical cross-sections of the structure. One can, thus, determine the cross-sections that have suffered plastic deformation. The MEMSCON model goes further to assess the degree of damage in these cross-sections based on the amount of dissipated energy and to assess the safety factor against global stability.

Vasilis Kallidromitis (TECNIC, Italy)

"Condition-Based Maintenance Management"

The speaker presented the methodology and the corresponding software implementation that has been produced in MEMSCON in order to provide building managers with (a) an estimate of repair costs of instrumented reinforced concrete buildings shortly after the cessation of the earthquake motion which is invaluable for quickly arranging for financing and (b) a much needed quick estimate of the scope and cost of rehabilitation work for instrumented reinforced concrete buildings damaged due to differential settlement between foundations which is the most common reason for building damage.

The above repair estimates are based on an assessment of structural damage of the building elements. This assessment is based on sensor measurements of strain and acceleration in case of an earthquake or strain in case of differential settlement between foundations. Moreover, the above repair estimates are part of an integrated package for the monitoring, structural condition assessment and maintenance/repair/ rehabilitation/strengthening management of reinforced concrete buildings.

Stefanos Camarinopoulos (RISA, Germany)

"**Decision-Support-System for the Rehabilitation of Buildings: The MEMSCON Project"**

Mr Camarinopoulos provided an overview of the Decision-Support-System (DSS) in project MEMSCON. The system architec-

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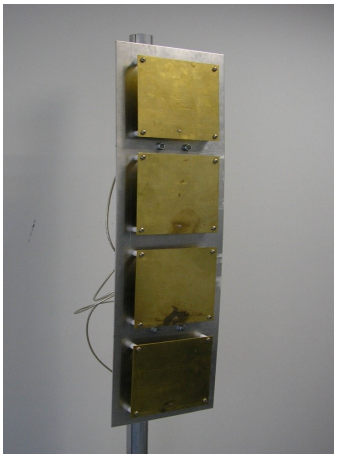


MEMSCON 4-element Antenna Array

Technical Sessions

ture includes a data base (DB) that stores all relevant information, data (structural element information and sensor measurements), rules, cases and relationships, an expert system that acts as an intelligent intermediary between the user and results that can be obtained by the system and the calculation modules that can assess the structural condition of the building and the type and cost of repairs.

The expert system includes a graphical user interface that provides the graphical environment with which the end-user can retrieve current and historical data from the DB, provides real-time alerts and warnings in case of abnormal conditions and allows the end-user to examine different scenarios for hypothetical situations.

Roberto Walder (Smartec SA, Switzerland)

"Integrated Structural Health Monitoring Systems for Buildings"

Mr Walder presented the SHM benefits (monitoring reduces uncertainty, discovers hidden reserves and deficiencies, insures long-term quality, allows structural management and increases knowledge), the 7 steps in the SHM methodology (identify structures in need of monitoring, acquire information on probable risks, establish expected responses, design an SHM system to detect such responses, install and calibrate the system, acquire and manage data and assess field data), the buildings in need of SHM (high-rise, large/tall in seismic areas, critical, large commercial and historical buildings and sports arenas) and case studies of successful SHM implementation in buildings.

Jose Vicente Fuento (ALDICO, Spain)

"Integration of the Technologies for Structural Assessment"

The speaker mentioned a number of successful SHM applications. In all cases the process involved problem observation, research and intervention.

The applied technologies for assessment included a 3D scanner-laser, infrared thermography, sonic tests and modal analysis. These provided input to 3D models for numerical simulation that resulted in structural assessment.

Monitoring reduces uncertainty, discovers hidden reserves and deficiencies, insures long-term quality, allows structural management and increases knowledge

Workshop proceedings available at www.memscon.com

Laboratory evaluation of SHM Technologies

Dr. Javier Molina (ELSA Laboratory, Joint Research Centre, EU)

"Severe Loading Tests on Large-Size Structures at ELSA Laboratory"

Dr Molina described the pseudo-dynamic method of laboratory testing and the implementation of this method in the SPEAR project on 'Seismic Performance Assessment and Rehabilitation of Existing Buildings.'

Prof. Daniele Zonta (University of Trento, Italy)

"Laboratory validation of intelligent structure technologies"

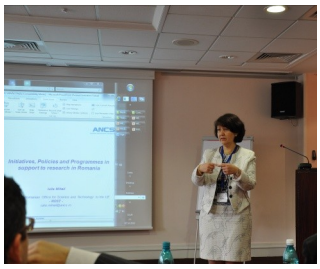
Prof. Zonta described the tests in the structural laboratory at the university of Trento in the context of project MEMSCON in order to validate the performance of both hardware and software under monotonic and seismic loads.

Prof. Ioan Vlad (Technical University of Civil Engineering (TUCB) Bucharest)

"Ambient Vibration Measurements. Current stage and Perspectives "

Prof. Vlad presented practical examples of health monitoring of existing buildings and engineering structures through ambient vibration measurements and recent or upcoming improvements in data acquisition and data processing. System identification using ambient vibration measurements presents a challenge requiring the use of special identification techniques, which can deal with very small magnitudes of ambient vibration contaminated by noise without the knowledge of input forces. The ambient vibration tests describe the linear behaviour of existing buildings and engineering structures, since the amplitudes of vibration are small. They can be used also to describe the linear behaviour of damaged structures and can help to perform more accurate structural models of analysis in the design process of strengthening. Therefore, the development of structural methods for in-situ measurements of full-scale partially damaged structures is of considerable interest.

Picture Gallery



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Dr. Markus Krüger (University of Stuttgart, Germany)

Dr. Angelos Amditis (ICCS), MEMSCON Coordinator

Dr. Sean Neylon (CEO Colibrys S.A., Switzerland)

Dr. Carmen Moldovan (IMT Bucharest)

Mr. Bogdan Fartat (IMT Bucharest)

Mr. Mikael Colin (MEMSCAP S.A., France)

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SEVENTH FRAMEWORK PROGRAMME

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