FP 7 Project Proposals

Proposals by VCE / Austria

1) European Structural Monitoring System (ESMOS)

Monitoring reaches each and every construction activity. The dominance for U.S. suppliers in terms of hardware and systems does not fully support the European advantage in methodologies and applications. A strong coordinated European monitoring system is desirable. It shall bring the current isolated systems to a stage of harmonization where sensor networks are easily applicable and will provide the way to future embedded systems. This includes the development of smart but cheap sensors, that can be embedded everywhere. The technical objectives should be but should not be limited to:

- A standard hardware to gain comparable structural information
- The development of wireless sensor systems
- The implementation of auto adaptive systems
- Mobile acquisition and assessment systems
- Instrumentation system intelligence
- The hardware for continuous monitoring systems for damage detection
- The hardware for periodic monitoring systems for damage assessment
- Monitoring systems for not accessible parts of structures
- Sustainable instrumentation and digital inspection hardware
- Smart sensor development based on the current nanoscale PZT fibre and film technology
- Finally cheap and reliable embedded sensors

Promising approaches are experienced on national level. There is no joint and organized approach visible. It would be desirable to form a strong European Consortium in an integrated project in order to achieve the critical mass to overcome the U.S. dominance.

The partnership shall be carried by the following institutions:

- Fraunhofer Institute in Germany on PZT fibres and film technology
- Torino Politec on MEMs
- University of Sheffield on innovative sensors
- Geosig on wireless systems
- Aplica on monitoring system integration
- IZFP on fibre optic sensor application
- SMARTEC on SOFO systems
- A partner on acoustic emission
- A partner on impact echo
- Laboratories for testing
- VCE as system integrator and database development

This project would be very much an SME based operation. Nevertheless contractors should be included in order to steer the development.

Helmut Wenzel, January 2006

2) European Structural Monitoring and Assessment Tools (ESMO-TOOLS)

Monitoring and assessment becomes increasingly important with the aging of our infrastructure. The current isolated methods shall be improved, enlarged and harmonized in order to reach a joint standardized European approach. The current advantage of European knowledge in this sector shall be increased and widened. The objectives shall contain but should not be limited to:

- Standardized parameter assessment tools
- Automated modal analysis tools
- Comprehensive knowledge based systems for assessment of records
- Inclusion of the human performance in the systems behaviour
- Tools and facilities for data mining
- Integration of image data processing
- Identification of generic algorithms for data harmonization
- Information design and visualisation including the users interface

Many isolated tools have been developed and software like Matlab is available. Nevertheless the practical user is not able to realize these scientific tools. A system with intuitive guidance on its use is necessary to encourage the conservative construction industry to use it.

Such a development should be of interest to all players within the construction industry.

An integrated project with representatives from all sectors of the construction industry would be necessary. The leadership should be with SMEs that have carried this development in the past. The development itself shall be done by these SMEs in collaboration with the relevant universities and research laboratories. The demonstration and proof test shall be done by the construction industry.

The following key partners are identified, but this project should not be limited to them:

- VCE for decision support systems
- KUL for system identification
- LMS for system identification software
- University of Sheffield for damage detection
- University of Aarhus for system identification
- Smart Tech for sensor integration
- BAM for vibration testing
- EMPA for structural control
- JRC for large testing facilities
- CESI for seismic monitoring

- AUTH for earthquake identification and microzonation
- Geocisa for practical monitoring
- Autostrade for the users needs
- Bilfinger & Berger for application at cables
- Bouygues for underground monitoring
- ARUP for railway monitoring
- Standardization bodies to be identified

The project should be organized in a way that a pool for research is available to allow the widest European participation.

Helmut Wenzel, January 2006

3) European System Identification Initiative (EUROSYSID)

Considerable progress has been made in structural system identification through projects of the 5th and the 6th framework program. During this development the open questions, research gaps and technology development needs have been defined. There is the necessity to carry out some basic works, to create the necessary basic knowledge. This basic research work shall be linked to the development of tools for practical application. The technical objectives shall include but should not be limited to:

- The information gained from satellite images on structural exposure
- The identification of total systems going beyond structural elements
- The role of non structural elements
- The identification of soil strata and groundwater tables
- Soil structure interaction measured by monitoring
- Damage detection algorithms
- Damage assessment algorithms
- Damage localisation algorithms
- Time domain methodologies for assessment
- Realistic application of neural networks and fuzzy logic

A potential partnership has to be carefully identified. The following partners are recommended:

- Universities: KU Leuven, University Aalborg, University Sheffield, University Porto, University Torino, University Milano, University Thessaloniki, University of Life science Vienna, University of Aachen and many others.
- Laboratories and institutes: BAM, EMPA, INRIA, JRC; CEA; Bristol, ENEL Hydro, NTUA
- SMEs: VCE, Aplica, Smartec, BBV, Geosic, etc.
- Industry to be identified

Helmut Wenzel, January 2006

4) Structural Assessment and Monitoring in Construction (SAMCO)

Many items of construction could benefit from monitoring. This includes environmental issues, safety and security, lifecycle monitoring, risk assessment and analysis, the understanding of the human factor and the information transfer in everyday operation. Monitoring is not applied widely because of its complexity and the difficult handling procedures. Every construction related project should have a work package on monitoring, which could be coordinated centrally to select and promote the best approaches. Such an activity would considerably enhance the application of monitoring and benefit the construction sector.

To achieve these objectives it is recommended to call for a major coordination action (CA). It could be organized similar to SAMCO, but with specific items of technical development work. This would bring a cross sectoral benefit. It would eliminate parallel development and help to achieve breakthrough with good and promising approaches. It could serve as a platform of interest on the subject which also takes care of the necessary standardisation and dissemination of results. The available organizational framework of SAMCO can be used and the project could start with a solid partnership who has already found each other.

A wider discussion on this idea shall be conducted in the near future.

Helmut Wenzel, January 2006

Proposal by Middle East Technical University / Turkey

- Bridges are important to the societies in a vital way. Lane/bridge closures would bring immense economical burdens. Research on bridge condition evaluation and health monitoring should be supported due to the high importance of the subject.
- Condition evaluation, health monitoring, remaining life (fatigue) evaluation is a must for strategically located and economically important bridges.
- Better understanding the aging mechanism/patterns based on bridge type, determination of structural property changes would help engineers to better design bridges by using improved codes/standards.
- Bridge maintenance intervals and extend of repairs can be optimized by means of SHM.
- An extensive search/documentation/categorization of available tools of monitoring (i.e., transducers, data acquisition systems, data storage and communication protocols, etc.) and methods including implementation stage would help to develop international guidelines for future monitoring projects.
- Dissemination of knowledge generated in proposed project would help development of centre of excellences in Europe.
- Certification program.
- Information Society Technologies might also cover bridge broadcasting of bridge conditions to citizens.

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Proposals by Politecnico di Torino / Italy

1) Mass-uncertain Tuned Mass Dampers for the Dynamic Protection of Buildings

In recent years, many passive and active control devices have been developed for mitigating seismic, wind, and traffic induced vibrations in civil engineering structures. Among them, the passive tuned mass damper (TMD) has been extensively studied because of its efficiency, reliability and low maintenance cost, notwithstanding his scarce robustness against mistuning, i.e. its effectiveness degradation due to its dynamic properties varying from their optimal value.

TMDs have found through the years a variety of technological implementations, including simple pendulums and multistage pendulums, inverted pendulums and roller pendulums, mechanically guided slide tables and masses on hydrostatic or laminated rubber bearings (not to mention tuned liquid dampers and semi-active or active devices), while the evolution of the classical single TMD into the multiple TMD during the '90s helped containing the hoary problem of TMD's insufficient robustness against mistuning.

Nevertheless, the number of passive TMD's installations on building structures is still limited to a few dozens around the world. One reason is that they are still perceived, like any dynamic control system, as too innovative with respect to traditional well-tested constructing practices, so that their use is circumscribed to those cases, such as vary tall and flexible buildings, in which recurring to traditional methods would not possibly provide the same performance, or not at all at a comparable cost. Another explanation is that in order for a TMD to be seismically effective, its mass is typically required to be a significant percentage of the structural mass, making it impractical and uneconomic to deploy heavy and cumbersome devices whose benefits may not even be experienced once during the whole life of the structure.

In short, it appears that new motivations are strongly needed to make tuned mass dampers' application to building structures more appealing.

Stemming from this observation, the present proposal presents the idea of turning into TMDs those non structural masses, such as roof gardens, tanks or technical implants, which are normally installed on top of buildings, so as to obtain a structural control system having low cost and minimal impact. Since such installations are susceptible of varying their mass (e.g. due to changes in the soil water content or in the vegetation growth, in the case of a roof-garden TMD), and therefore of potentially changing their frequency and damping, assessing and enhancing robustness against mistuning becomes a crucial issue for these new family of 'mass-uncertain TMDs'.

Turin Research Unit has been engaged in this topic for the last few years.

Attention has been devoted to studying to which extents the mass uncertainty decreases the control effectiveness of traditionally optimized single and multiple TMDs and how a proper robust selection of the control parameters can help reducing such performance impairment. A new type of rolling pendulum device capable of maximizing robustness against mass uncertainties has been proposed, relying on a rolling surface specifically designed for preserving tuning even at large amplitudes of motion. An experimental campaign has been conducted for assessing the potential advantage of using an inexpensive rubber dissipation mechanism instead of traditional dashpots as the source of damping.

The fundamental achievement from these preliminary studies is that through an adequate mix of technological solutions and design criteria, mass-uncertain TMDs can preserve most of the effectiveness of their constant mass traditional counterparts, with the advantage that their mass is already present on the building and they are therefore cheap, unobtrusive and no structurally demanding.

Several possible research developments of these initial results can be figured out.

The construction of a prototype of rolling pendulum TMD would be required in order to experimentally test its behavior and to grasp the technical difficulties lurking in a practical implementation. Both alternatives of inserting a viscous dashpot in parallel with the pendulum system and sandwiching rubber sheets between the rolling surface and the ball bearing should be explored, and their respective trade-off between cost and performance pointed out.

Further theoretical in-depth studies would be recommended to understand under which circumstances a liquid storage tank of variable content can be effectively turned into a mass-uncertain TMD. The question arises about how to deal with the sloshing phenomenon, which might either be negligible, thus allowing a rigid body representation of the liquid mass, or be significant around the natural frequency of the structure, thus requiring a more complex modeling and potentially reducing control effectiveness. On the other hand, the possibility could be investigated of exploiting the sloshing effect as well, to obtain a hybrid solution of "tuned mass plus liquid damper", where the mass uncertainty concept would be extended to cover the variability of effective mass which is a well-known property of any classical tuned liquid damper.

A feasibility assessment would be strongly advised to justify the use of mass-uncertain tuned mass dampers in typical situations. Their advantage with respect to other passive dissipation systems or to the conventional strategies of strength-based approach and ductility design should be evaluated, in relation to a representative ensemble of current ordinary buildings. Practical technological issues should be addressed for each specific kind of implementation, for instance due to the consequences of disconnecting and letting vibrating implants which are typically clamped to the structure.

A final possible development could be a semi-active solution instead of the passive one. It is expected that semi-active control of the stiffness and the damping coefficient of the TMD would further increase the robustness of the device against variations of its mass, while simultaneously dealing with possible changes in the dynamics of the building structure as well. A trade-off between cost and performance exists which would deserve to be explored in order to stress the relative advantages and drawbacks of the passive and semi-active strategies.

2) Identification of Masonry Structures

Identification is unanimously considered indispensable for an accurate numerical model of a structure, especially when dealing with materials and structural schemes which cannot be easily identified (9,12,16). It must be noted that structural designers are accustomed to working with models enabling the safety of a structure to be evaluated in an unequivocal manner, whilst less interest is attached to model accuracy for the forecasting of actual mechanical response. However, in recent years, structural design has been flanked by new disciplines, such as structural diagnosis and monitoring and, consequently, identification on the basis of the vibration signals acquired during dynamic tests has taken on a primary role (1-16).

Whatever the objective is practised for, the aim of structural identification is to provide a solution to an inverse problem. Inverse problems are often ill-conditioned, so that interpretation of experimental results is as much accurate and reliable as many parameters are available (9), this being the most prominent difficulty in the formulation of effective identification techniques. Whilst the diagnostic activities aim at estimating type and entity of possible variations in the parameters of a structural model, structural control and rehabilitation oriented model updating presuppose the availability of a truly predictive model.

The use of “ad hoc” excitation often proves very costly and sometimes difficult to put into practice, as in the case of old masonry structures or severely damaged buildings; furthermore it may involve other problems, by causing breaks in roadways (e.g. bridge testing) or production activities. In such circumstances, the use of special techniques exploiting natural excitation offers the advantage of shifting the burden from the stage of data acquisition to the processing stage.

The importance of this research field is widely recognized at an international level, and a proof of this is constitued by the increasing diffusion of journals expressly devoted to structural identification and diagnostics, such as Mechanical Systems and Signal Processing, and specialized international conferences, such as the International Modal Analysis Conferences, organised by the Society of Experimental Mechanics. Furthermore, these topics occupy an increasingly wide space on traditional journals, such as the Journal of Sound and Vibration or the Journal of Engineering Mechanics (ASCE). At an European level, some relevant projects on these subjects have just been completed or are in progress (BRITE EURAM, COST F3,….) and a few specific networks have been dedicated (CONVIB, SAMCO etc.). At an Italian level, the seismic protection and the identification of ancient heritage structures typically are among the principal issues of the Italian Conferences of Earthquake Engineering, in which, recently, a number of sessions specifically devoted to structural identificantion have been introduced.

This Research Group for more than a decade has been working on structual identification and diagnostics (17-36). In a first stage, members of the group worked in the field of “output only” structural identification via autoregressive algorithms (ARMAV) in the time domain (17) and, at the same time, were involved in the application of artificial intelligence to structural diagnostics by symptom based approaches (18,19,24).

The cultural exchange and cooperation established with other research groups the Politecnico di Torino (Departments of Mechanical Engineering, Aerospatial Engineering and particularly Electronics), interested in analogous applications, has brought the proposers to important developments in the advanced processing and diagnostic interpretation of structural response signals (24,25-27). Researches in the field of time-frequency analysis of dynamic signals gave as result a new “output only” method for structural identification, which retains its validity also in non-stationary consitions; this technique has been compared with other methods thanks to the partecipation in “Round Robin Exercise” programs and Blind Tests extended to several international research untis, whose results are often mentioned in literature (Queensborough Bridge, Vancouver; Alhambra Building in S. Francisco, San Gaudenzio dome in Novara, Matilde tower in San Miniato (Pi)) etc. (22,25).

The experience acquired in the field of signal processing inspired more recently the idea of using, in the “output only” structural identification, estimators of instantaneous amplitude and phase relationships between channels, which are defined in the joint time-frequency plane. This technique, which has been widely discussed by the authors in international conferences and published, in a furtherly developed form, on the Journal of Sound and Vibration (29,31), does not require strong assumptions on the excitation type, as well as on the linear dynamic model. Significative applications of this method have been performed on the ancient bell-tower of the SS Annunziata church in Roccaverano (Asti-Italy) (30,35,36), a masonry structure that had suffered earthquake damage, and gas pipes of the Italian company for gas distribution (Italgas) (32).

The question about the application of these techniques to masonry structures should be considered a still unsolved issue and, more specifically, researchers should investigate whether the sensitivity of modal parameters obtained from identificationis is sufficient to allow the detection and identification of localised or distributed damage. One may expect that the actual existence of a fault would cause a number of symptoms that are small if considered singularly, but significant as a whole, among them: modal frequency and shape deviations, unexpected irregularity and dyssymetry in the global dynamic behaviour, appearance of new vibration modes, damping growth and local dissipative behaviour, non-linear effects. The presence of several small symptoms might make a direct and deterministic interpretation difficult; the proposers have personally experienced that, in this situation, “pattern recognition” and neural techniques may reveal to be very effective (19,24,28). Alternative methods are those founded on updating numerical models: model correction is based the results of a previous structural identification (model updating techniques) (7,9,16). Not only is such an approach useful for a direct diagnostic evaluation, but it also represents a first step in order to achieve a complete numerical model, which, also by taking into account irregolaries and dissymmetries, can support reliable predictions and choices about the repairement interventions.

More recent studies addressed also the problem of linear and non-linear identification via instantaneous time frequency estimators (37-49). In particular, non-linear system identification is a subject of particular interest for researchers belonging to different technical and scientific areas: in the field of civil engineering, the identification of mechanical non-linearity has been faced in a limited number of applications, according to different approaches: by identifying experimentally the parameters of a non linear analytical model; by measuring the reduction in modal parameters with increasing actions; by introducing non-linearity only in the numerical model downstream of a linear identification.

The dynamic behaviour of masonry structures is really complex and seldom it can be described satisfactory by a linear model; moreover, the reliability is a fundamental issue especially when the results of system identification techniques are used for updating mathematical models and for structural safety evaluation.

From the mathematical point of view, one of the most important sources of uncertainty in the identification process is related to the modelling of the dynamics of the system under study. A fairly general approach for modelling non linear systems is based on the Volterra series representation for the input/output relation (50-54): system’s output is expressed as sum of infinite terms which are the outcome of n-fold convolutions between the input and characteristic functions of the systems, called Volterra kernels; the dual functions in the frequency domain of the Volterra kernels are the so-called higher order frequency response functions or generalized transfer functions. While in the linear case the input-output behaviour of a system is completely described by the first-order frequency response function, for a non-linear system, in general, the dynamic behaviour is fully described from the knowledge of a theoretically infinite sequence of functions.

Many methods are now available for identifying the dynamic properties of non linear systems: like in the linear case, different techniques are related to different way of exciting the system (“input-known” or “output-only” conditions (50-54)), from the domain in which the techniques are formulated and from the “a priori” hypothesis made on the type of non-linearity. A recent research of this group presented the results of the identification of Volterra's nonlinearities through time-frequency instantaneous estimators (55).

Another research subject regarded the identification of masonry arch bridges using Canonical Variate Analysis (CVA) techniques, as well as autoregressive methods (56-57).

Intense are cultural exchanges and cooperation of the group members with foreign universities and research centers (University of Nagoya, Washington University of San Louis, Boston University and North-Eastern University of Boston, ENPC Champs sur Marne, University of Illinois at Urbana-Champaign, University of Illinois, University of Kassel).

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Proposal by EPFL / Switzerland

1) Configuration of Sensor Systems

This involves developing rational and systematic methods for determining optimal locations and required precisions of sensors. A criterion for selection is the number of candidate behaviour models that can be separated through measurements. Candidate behaviour models are determined from ranges of possible future values of model parameters and model types. For example, different combinations of values for support conditions, cracking locations, elastic modulus and deterioration result in thousands of candidate behaviour models. The best place to measure is where predictions of these candidate models are most widely dispersed.

2) Multi-model Structural Identification

Case studies at EPFL have shown that due to errors in measurements and model predictions, the correct behaviour model is rarely the one that exactly predicts measurements. This project would develop a methodology for structural identification that begins with a population of candidate models. Candidate models are defined by variations in modelling assumptions and errors in modelling and in measurements.

For more information:
the following papers have already been published in these fields:

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Proposal by University of Sheffield / Great Britain

1) Proposal on Safety of Civil Structures under Crowd Loading

Structures such as footbridges and grandstands are being used for crowd loading scenarios that were either not considered during construction or are inadequately covered by design codes or guides.

In a number of extreme cases structural collapse has occurred, but the main concerns are expense for retrofit if the structure is observed to be dynamically lively, or crowd panic (with possible disastrous consequences).

There are hence needs and justifications for a comprehensive study on the nature of crowd dynamic loading that considers factors such as nature of event generating the crowd, the density of the crowd, whether the crowd is stationary or in transit, how people synchronize and the contributions of psychological and physical factors on behavior.

Such a study would involve instrumentation of assembly studies, comprehensive motion capture and analysis equipment, interviews, advanced (virtual reality) simulations of crowd dynamics and structural analysis.

The research would be conducted on a sample of grandstands and footbridges in the UK.

2) Calibrated Structural Systems for Loading Assessment

Loading code development is a major factor on design but there remain significant gaps in knowledge about loading characteristics (extreme values, distributions etc. for seismic and wind loads). A structure that has been characterized reliably (through analytical modeling validated by dynamic assessment) can be used as a load cell so that loading can be inferred from response via inverse analysis. Remarkably few studies of this type have been conducted with respect to wind loads –including their dynamic component- and building instrumentation for seismic response has usually excluded the critical free-field motions. There is a particular lack of information about multiple-support seismic excitations.

A few key structures representing the range of short and long span bridges, medium to high rise buildings would be dynamically assessed, permanent instrumented and linked to software tools for building up a database of response -and hence loading- characteristics.

3) Wireless Real-time Data Acquisition System

Wireless systems are being developed but the civil market is still too small to justify commercial development. Nevertheless, given that cabling represents an archaic technology contributing disproportionately to difficulties in experimental evaluations, there is clearly a need to a massive technology improvement. Systems do exist that operate as independent seismometers synchronized out of real time, but the real need is for live data acquisition allowing for immediate adaptation of measurement strategies, fixing sensor faults etc.. such a system will significantly enhance ability to calibrate structural models and to conduct level 2/3 periodic monitoring assessments.

The research would develop a prototype, provide development funds for a commercial solution and equip key EU institutions.

4) Workshop and Platform for Technology Transfer

Given that a key issue retarding SHM applications is lack of awareness of end users.

Highways managers, bridge operators and other stakeholders are simply not aware of the capabilities (and limitations) of SHM. SAMCO has provided a model for how to do this, but a bigger push into industry is required. hence one or more expenses-paid workshops inviting these key industry personnel to discuss experiences with academic and commercial organizations involved in SHMs should have significant impact and open doors for more real-world applications.

Proposal by AUTH / Greece

FP7 : NATURAL HAZARDS – OVERALL OBJECTIVES

Disasters related to climate, such as storms, droughts, forest fires and floods and geological hazards, such as earthquakes, volcanoes, landslides and tsunamis, will be studied on the basis of R&D projects.

Managing natural disasters and reduction of risk requires a multi-risk approach. There is a need for improved knowledge, methods and integrated framework for the assessment and mitigation of hazards, vulnerability and risk. There is also an urgent need to improve technologies and engineering related to the mitigation of natural risks.

Innovative techniques for assessing, mapping, prevention and mitigation strategies including consideration of economic and social factors need to be developed.

Better understanding of the processes and physics of the phenomena, the development of improved modeling and engineering techniques and methods and the development of innovative techniques to monitor, forecast and mitigate the risks are the principal strategic objectives. Development of innovative and cost efficient techniques and methods to assess vulnerability and for upgrading and retrofitting existing buildings, lifelines, critical facilities and infrastructures is of major importance. Development of modern technologies to monitor, mapping, archiving, all elements exposed to major natural hazards and risk is of prior importance.

The development of early warning and information systems related to the above objectives shall be also considered. Societal repercussions of major natural hazard and synergies among hazards will be also studied.

a) Key research needs on specific hazard level

Earthquakes

- Fundamental research related to the seismic performance of all kind of engineering structures (buildings, lifelines and infrastructures). Development of large scale facilities (laboratory and in-situ) at European level is of prior importance.
- Fundamental research related to the physics of earthquakes generation and propagation of seismic waves in complex media. Development of permanent arrays and in-situ large scale facilities is of prior importance.
- Development of innovative techniques and methods to improve the seismic performance of buildings, lifelines and infrastructures like bridges and tunnels (including their components).
- Development of improved methods for the vulnerability assessment of buildings, lifelines systems and networks.
- Development of integrated methods for the vulnerability assessment and the seismic risk management of cities and historical centers (protection of cultural heritage) including their infrastructures.

b) Key research needs on a more horizontal level (multirisk approach, vulnerability, risks, mapping etc).

Earthquakes

Multirisk approach in a city level is necessary in order to improve preparedness and risk mitigation.

Explanatory comments: Vulnerability assessment of buildings is affecting the closure of roads and thus the vulnerability assessment and risk mitigation of roadway and transportation networks and systems is directly related to the vulnerability and losses of buildings. The vulnerability of waste water and potable water system may affect seriously the vulnerability assessment of critical facilities like fire stations and hospitals.

So an integrated approach accounting for the synergies among building and lifelines and the vulnerability of different elements at risk is mandatory for an efficient risk management.

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Proposal by KUL / Belgium

- First of all: we had already two excellent monitoring projects focused on **Windturbines** (SCYLLA) and **Light Rail Track Infrastructure** HIPER-LIGHTTRACK)**.** Why enforce ourselves to other - less socially relevant - applications of monitoring: let's at least re-launch these two previous projects.
- Another interesting idea could be (remember the presentation of Claude Dumoulin in Zell am See): monitoring **at the construction phase** (here there is a direct interest of the contractors!).
- Other idea: **heavily loaded (large span) roof structrures**. Remember the recent collapses (Reichenhall, Katowice-Chorzow, Russia) due to snow load. In all these cases the snow load seemed to be 'within the design limits'. If true, then there should be already an hidden damage present in the structure (Reichenhall: possibly lacking strength of the glue in the laminated timber girders) or an error it the design: could proper vibration monitoring give alarm at the right time?

Proposal by ENEL / Italy

Topic: Recent evolution of glacial and periglacial alpine areas: rock falls related to permafrost degradation, ice falls and supraglacial lake formation and outburst. Study of the phenomena, hazard assessment, warning system design, risk management.

Objectives

1- study of permafrost distribution and evolution in alpine areas, with reference to rockfalls in high mountain areas triggered by permafrost degradation
2- study of glacial risk phenomena in alpine areas, with reference to hanging glacier snouts and periglacial / supraglacial lake formation, occurrence and evolution (outburst)
3- Forecast of rock- and ice-falls in high mountain areas: triggering factors, monitoring, failure time forecast, runout prediction
4- Development and Integration of Monitoring and surveillance techniques
5- Hazard assessment and risk management

Overview and recent events

Due to the increase of the mean annual air temperature since the second half of the ‘80s and the occurrence of extraordinary hot summers (e.g. summer 2003), unexpected and relatively unknown phenomena are presently affecting glacial and periglacial areas in the Alps. Tourists and people living in mountainous areas are presently exposed at raising risk.

The most frequently occurring phenomena are:

- ✓ rock falls related to permafrost degradation
- ✓ ice falls from hanging glacier snouts, seracs, etc.
- ✓ formation and outburst of supraglacial lakes

Some recent events:

- ✓ summer 2005: ice fall from the eastern slope of Monte Rosa, Italy (500.000 to 1 million m3)
- ✓ summer 2005: Dru rock falls
- ✓ summer 2005: emergency related to the formation of a supraglacial lake on the Rocciamelone glacier (Italy-France border), with a volume of more than 600.000 m3; the lake was artificially drained in order to avoid imminent outburst
- ✓ summer 2004: Thurwieser rock avalanche (> 2 million m3)
- ✓ summer 2003: Cheminée de l’Arête du Lion (Matterhorn) rock falls
- ✓ summer 2003: Marco e Rosa Hut (Mt. Bernina italian slope) rock fall
- ✓ summer 2002: emergency related to the formation of a supraglacial lake (Effimero Lake) on the Belvedere glacier (Monte Rosa, Italy), with a volume of 3 million m3; the outburst occurred in June 2003: fortunately no sudden but gradual increase of discharge values were recorded

Tasks:

- ✓ Creation and management of a data bank (GIS) of rock and ice fall events
- ✓ Creation of an inventory of unstable glaciers (GIS)
- ✓ Measuring and monitoring morphological changes and activity of representative high mountain rock slopes (ground based laser scanner surveys, ground based digital photogrammetry surveys, seismic / microseismic networks, surface and deep displacement measurements, ...)
- ✓ Measuring and monitoring rock wall thermal regime
- ✓ Measuring and monitoring surface and deep ice motion and physical properties of ice (temperature, stress, strain, ...)
- ✓ Development of specific monitoring techniques
- ✓ Integration of satellite and ground based monitoring techniques
- ✓ Modelling permafrost distribution and evolution
- ✓ Modelling ice motion and strain-stress distribution within ice
- ✓ Modelling ice and rock fall run out
- ✓ Failure time forecast
- ✓ Warning systems and decision tools
- ✓ Guidelines and procedures for hazard assessment by local authorities
- ✓ Emergency management
- ✓ Application to selected test sites
- ✓ Assessing the uncertainty propagation for the entire analysis chain, from primary data acquisition, through models up to the final output that is mend to support the decision-makers.

Proposal by EAEE - ESC / United Kingdom

Natural Disaster Mitigation. Proposal for a Research Theme in FP7

Comments by the EAEE and ESC on the EU Document *Thematic Priorities in FP7*

Introduction

1. The purpose of this communication is to propose a Research Theme for FP7. The title of the theme would be ***Natural Disaster Mitigation***. Sub themes would include:

- Geological hazards – earthquakes, volcanic eruptions, landslides and avalanches
- Climatic hazards – floods, windstorms, heat-waves and cold weather
- Wildfires

2. This proposal has been drafted by and is supported by the Executive Committees of the European Association for Earthquake Engineering and the European Seismological Commission. Membership of both these bodies extends to countries in the European/Mediterranean area outside the present EU, but each is able to speak for the research community across the EU.

Justification

3. Natural disasters of all types – earthquakes, floods, windstorms, volcanic eruptions, wildfires result in average annual losses across Europe of around Eu15-20bn. In addition they cause significant numbers of human casualties, loss of homes and livelihood, and cause a set-back to economic development wherever they occur. There is also the potential for a single loss – from an earthquake, flood or volcanic eruption - of the order of Eu100bn, greater than any which has occurred in the past.

4. The EU has supported research on all these topics for more than two decades, and much has been achieved during that time, especially in enhancing the understanding of the basic mechanisms involved and in limiting the future impacts by better design practices. But much remains to be done in understanding and reducing the vulnerability of the EUs communities and built environment, and in building our capacity to deal with the hazards we face. Research budgets have been neither sufficient in quantity, nor effectively enough targeted, to achieve a real breakthrough. In this respect the EU lags very far behind our industrial competitors in Japan and the United States.

5. The eastward expansion of the EU already in place, and that envisaged for the future, will both bring in new territories with grave natural hazards threats, highly vulnerable infrastructure and recent experience of terrible losses, and at the same time enlarge the EUs existing pool of research expertise.

6. The FP7 period 2007-2013 therefore represents an unprecedented opportunity to harness emerging knowledge and technology to bring losses from natural hazards under control throughout the European area in order to improve the safety of its citizens and to safeguard their economic security.

Research approach

7. To achieve a decisive breakthrough towards natural disaster mitigation will require

- A programme of research at the EU level

- A programme which integrates research on all types of disaster
- A substantial increase in resources
- A multi-disciplinary approach involving physical scientists, engineers and social scientists
- Better collaboration between the research community, government and industry
- A managed programme

8. ***A programme of research at the EU level is needed***:

- to create and coordinate a critical mass of research expertise
- to create(or improve/further development) the necessary research infrastructure, including large scale research facilities
- because the phenomena being studied and their effects are truly transnational
- because national budgets alone are inadequate.

The goal of disaster mitigation is consistent with many existing EU policy goals – in environmental protection, in protection of the cultural heritage, in transport, in health, and in social affairs. If it is the aim of the EU that citizens throughout Europe should enjoy comparable living standards, this must include comparable levels of protection from known natural hazards.

9. ***A programme which is integrated across the whole field of disaster mitigation is highly desirable*** for effective management because:

- a multidisciplinary research approach involving physical and social sciences and engineering is common to all fields
- there is much overlap in methods, approaches, and research facilities
- in the design of facilities, a multi-hazard approach is likely to be cost-effective
- the user-community is the same in each case, consisting of designers and builders, urban authorities, estates managers, insurers and civil protection agencies.

10. ***A substantial increase in resources is essential*** because current funding of disaster mitigation research in the EU is at a much lower level than our industrial competitors in the USA and Japan. One result is that we are lagging behind those countries in bringing losses under control. Another result is that the development of technologies for scientific monitoring, for improvement in the performance of structures and for experimental and simulation studies is increasingly concentrated in the USA and Japan, leading to a loss of technological leadership and of export markets to the huge disaster-prone countries in Asia and the rest of the world.

Additional resources are needed to provide for

- Much enhanced monitoring networks (including satellite monitoring)
- The development of research infrastructure and large scale facilities
- Creation of a directed long-term research programme
- The formation of networks and centres of excellence on a variety of topics
- The mobility of researchers

11. ***A multi-disciplinary approach is needed*** because effective action to reduce disasters requires coordination across several overlapping disciplines. Earthquake risk mitigation for example requires:

- Understanding seismic hazards – developing models of earthquakes based on geophysics and observation
- Assessing and reducing earthquake impacts – developing tools to simulate behaviour of buildings and urban systems, and devising technologies to build more earthquake resistant structures and strengthen existing ones
- Enhancing public understanding and community resilience – developing the means to communicate effectively about the options available, and to enable communities to devise their own protection strategies

These three areas are traditionally the domain of physical scientists, earthquake engineers and social scientists respectively. But none of these groups can operate effectively or achieve goals of value to society unless they interact closely and understand each others methods and problems.

12. ***Better collaboration between the research community, government and private companies is needed*** to ensure that the research supported by the EU makes the most impact possible on its intended users. Governments stand to benefit enormously from the reduction in future losses which should flow from this research; insurers will benefit from a better understanding of risk as well as reduction in losses; and the construction industry will benefit from the exploitation of the new techniques developed. A closer involvement of both government agencies and private companies in the formulation, execution and financing of natural disaster research is therefore easily justified. The mechanism of a “technology platform” (as proposed in para 20 of *Science and Technology, the Key to Europe's Future* COM(2004) 353), would be an excellent vehicle for such a collaboration at a European level.

13. ***A managed programme is needed*** to achieve coordinated outputs and a long-term strategy. Research effectiveness in previous Frameworks has been hampered both by the short time-horizons of each Framework (enough for a single round of projects to be formulated, commissioned and executed), and by the lack of a coordinated scientific management. An attempt to improve the latter has been the introduction of Integrated Projects in FP6, but this has the unintended and very unfortunate result of creating too large and unwieldy research groupings, and of converting some of Europe's most able researchers into managers in order to offload the management from the Commission. The Commission has the opportunity, in FP7, to set up a programme with long term goals such as the very effective National Earthquake Hazards Reduction Programme (NEHRP) in the USA. Much could be learnt from a detailed examination of the structure and management of NEHRP and other US managed programmes such as that of the California Applied Technology Council.

Earthquake Risk Mitigation Sub-theme

14. As an element of an overall Natural Disaster Mitigation Research Theme, the EAEE and ESC envisage that it will be essential to address at least the following topics under FP7:

- Better fundamental seismological databases and instrumental networks (regional and local to specific buildings- test sites) for earthquake monitoring
- Improved hazard mapping
- Vulnerability assessment of buildings, lifelines, infrastructures etc Protection of historic buildings and centres
- Common standards of protection for existing public buildings, highways and other infrastructure

- Improved methods for intervention in the existing fabric to increase earthquake resistance
- Better design of structures and foundations
- Understanding human behaviour in earthquakes and public response to risk
- Building community resilience and response capability

More detail of these topics will be provided in due course.

Fit with the EUs criteria for identifying thematic domains

15. Contribution to European Policy Objectives.
The proposed research theme will make a vital contribution to Europe's aim of achieving sustainable economic growth. Societies which are constantly coping with the consequences of natural disasters do not achieve sustained growth. This has been shown by the impact of storms and floods in the EU countries in 2000. The research theme will contribute to policy objectives in many areas – in environmental protection, in protection of the cultural heritage, in transport, in health, and in social affairs. The creation of a uniform level of protection of the citizen from death of injury or loss of livelihood though natural disasters is clearly consistent with EU policy objectives.

16. European Research Potential.
The proposed research theme clearly has potential both for the creation of research excellence and for converting the results into social and economic benefits. At a scientific and technical level, natural hazards research in Europe leads the world in many areas. This has been achieved partly through previous EU funding, and future funding at an increased level is needed to maintain that status in the face of growing international competition. The potential now exists to convert that research into social and economic benefits to a much greater extent than has been achieved so far, and this is the challenge that must drive the research activity in FP7.

17. European Added Value
The arguments for research to be carried out at a European level are set out in Para 8. These are essentially to create a coordinated approach, a critical mass of researchers, and an adequate research infrastructure. Each of the phenomena of this proposed theme are common to many EU countries, and their threats and effects cross national boundaries. Through the EUs support over the last 2 decades the research culture is genuinely European. In natural disaster research European Centres of Excellence already exists and must be fostered and promoted. Europe is seen by the rest of the world as being a single entity. Fragmented national efforts are now unthinkable.

The Executive Committee, European Association for Earthquake Engineering (EAEE)
The Executive Committee, European Seismological Commission (ESC)

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Proposal by MPA / Germany

Engineering Structures – Industrial Plants – Power Plants, Conventional and Renewable Energies

An important field of activity for further research is:

"Advanced condition based monitoring" including understanding of damage mechanism with the aim of realistic determination of life time consumption

The basis of the herein specified type of condition orientated maintenance is the detailed knowledge about the damage mechanisms (e.g. fatigue, plastic deformation, wastage, corrosion, etc.) acting during operation. If they are known, measurement results allow a continuously evaluation of the damage mechanisms on the service life of a component. In combination with effective measurement systems and advanced analysis techniques the beginning of the damage progress can be observed early enough. This makes it possible to plan long term in advance and to find the ideal point in time before the repair or replacement of components. Thus, the risk of failure of the component can be reduced on a minimum.

The causes and consequences of damage mechanisms and their monitoring should be implemented already during the design stage of the engineering process.

An important new area for implementation is the *Renewable Energy Market* to increase Economical Benefit and Safety on Components such as

- Wind Turbines (power transmission, not accessible pillar points)
- Offshore Constructions (e.g. flanges or foundation in offshore constructions),
- Wave Converters,
- Piping etc.

A condition orientated maintenance of technical plants supplies information about the condition of plant components to the operators in time. Thus damage is prevented in time. Therefore a strategy avoiding reactive and cost-intensive maintenance measures in the case of damage is necessary. In combination with effective measurement systems and advanced analysis techniques the beginning of the damage progress will be observed early enough. This makes it possible to plan long term in advance and to find the ideal point in time for the repair or replacement of components. Thus, the risk of failure of the component can be reduced on a minimum. The measurement quantities and measurement sites to determine are chosen in this way that an exact quantification of global and local loading and determination of the life time consumption is possible together with numerical studies.

The basis of the specified type of condition based maintenance is the detailed knowledge about the damage mechanisms like

- Fatigue
- Plastic deformation
- Wear
- Corrosion

<u>Expected Results</u>

E.g. highly loaded zones e.g. of pillar-construction (flanges, screwed connections and other points with stress concentrations) of wind turbines or offshore constructions shall be localised by means of computed models. A realistic load input will be provided from measurements. A full stress and strain analysis is then possible for points not accessible. Furthermore, loading and load collectives will be classified e.g. according to the magnitude of relevant wind velocity. Fatigue analyses determine the usage of life time. Thus the rate of the load collectives per year and therefore the relation to the whole time of operation can be determined by this procedure. Service life prognosis is now possible allocated to meteorological data and the material characteristics necessary for fatigue analyses. It is also possible to evaluate integrity assessments and to derivate the requirements of inspection intervals.

Proposal by JRC / Italy

Resistance of Critical Constructions to Extreme Loads

(Subject proposal for discussion and further definition and improvement)

Abstract

General objective

The general objective is the protection of the population against the consequences of structural damages of critical structures in case of extreme loads due to external threats, strong earthquakes and sabotage.

The research will be mainly addressed to partially and fully embedded containment structures taking into account the soil structures interaction (SSI) effect.

Specific case studies could be the underground stations and the nuclear reactor buildings, for which embedment is an option retained for the future.

Unique in-field tests

The understanding of the SSI, in particular for embedded structures, needs from in-field tests (unique for Europe) on large-scale models, thus needing a large geographic site adequately instrumented where it is allowed to perform tests using blast explosion to mobilize the mass of the ground interacting with the structures of the model.

International benchmark

The project will include also an international benchmark (focused on analysis and interpretation of the unique in-field tests) involving key research institutions and universities in the world, thus creating the basis of wide international collaboration for the diffusion and valorisation of the project outcome.

Customers

The action is intended to provide support to the European Authorities and Organizations concerned by the security of the population and/or in charge of the definition of the European standards for construction as well as International Organizations concerned by the risks associated to the vulnerability of partially and fully embedded structures under natural or man induced extreme loads.

Costs and duration

The project costs could be of the order of 5 MEUROs and should last not less than 5 years (3 years for the execution and 2 year for the completion of the international benchmark and the related technical document).

Partnership Core Group

The Partnership core group as proposed by JRC could include the following Organizations (still to be contacted and therefore not yet involved in the proposal):

Aristotle University of Thessaloniki for the large-scale in-field tests to be performed at the EUROSEIS-TEST-SITE in VOLVI, Thessaloniki, Greece (Contact: Kyriazis Pitilakis, E-mail: pitilakis@civil.auth.gr, coordinator of the FP5 EUROSEIS-RISK project);

University of Bristol for the relevant competences in systems reliability theory applied to the assessment of the structural damage and the risk associated to unforeseen loads as due to terrorist attack
(Contact: Colin Taylor, E-mail: colin.taylor@bristol.ac.uk);

Commissariat a l'Energie Atomique (owner of the largest Shaking Table in Europe) for preliminary dynamic tests and the link with the buildings of the nuclear plants
(Contact: Pierre Sollogoub, E-mail: pierre.sollogoub@cea.fr);

European Laboratory for Structural Assessment (owner of the largest Reaction Wall in Europe) for preliminary pseudo-dynamic tests and the technical coordination of the International Benchmark
(Contact: Vito Renda, E-mail: vito.renda@jrc.it).

Proposal by IBDiM / Poland

The IBDiM probably will not be able to prepare a project proposal by himself, but we would like to present possibilities of our research activities in the area covered by SAMCO and bridge engineering.

1) Assessment methods of existing, old bridges

The methods are based on bridge behavior analysis under various load types:

- service load
- testing load
  - diagnostic bridge load testing
  - proof load testing.

Possible activities:

- bridge structures of various types testing;
- deflection, stresses and acceleration momentary measurements under various load sorts;
- development and optimization of assessment methods of existing, old bridges.

2) Long term monitoring system for bridge assembling and service live

The system is based on small size and low-cost unique autonomous recorders. The recorders measure three quantities, which appear in bridge element testing point during assembling and service. These are the strain (stresses), the acceleration and the temperature. Measurements with the use of the electric resistance wire strain gauges are assisted with measurements done with photoelastic coating method to eliminate possible errors. The recorder can be fixed to the bridge element at the production plant and measurements can be conducted during all sequence of bridge erection stages. Thanks to these measurements it is possible to define stress levels derived from superstructure’s dead load and complete with stress levels caused by service loads.

Possible activities:

- long term monitoring of the various categories of bridge structures during assembling and exploitation;
- analysis of the components of stresses levels (residual, internal and service) occurring in bridge structures connected with different type of bridge assembling and loads;
- development and optimization of long term monitoring system.

Road and Bridge Research Institute (IBDiM)
Bridge Structure Research Laboratory

Proposal by University of Liège / Belgium

Ideas to be Used for Sensors and Sensor Networks

- increase 50 to 100 Hz on "intelligent instrumentation system" as aeolian vibration (Von-Karman Vortex shedding) on power line, cable may have dangerous vibrations (for ageing) up to these ranges, even if most of the time 10 to 30 Hz is the worst range.
- wireless diagnostic of sensors and sensors systems from the ground, e.g. by infra-red beam able to receive appropriate informations in order to diagnose systems and being able to put them in sleep mode in case of necessity.
- communication between sensors in the vicinity to better transfer informations without ground link on several kilometers.
- local treatment in the sensors system in order not to overload memories and to transfer digest data to base stations (may be this is included in "mobile acquisition..."
- to profit from local environment to catch energy from the structure itself, not only from vibration, wind, but also from existing electromagnetic field (the case of power lines).
- to profit from system features to get automatic system positioning on a span, if needed
- to use radio wave link to download new software into the system if needed (repare bugs, new treatment, etc...)
- the assessment is not necessary needed on board but is needed in some remote location (national dispatching for power lines), which need appropriate links and certainty of information received as major decision may be taken in a few minutes delay.

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Proposals by Bauhaus-University Weimar / Germany

Even though the monitoring procedure and equipment (sensors, cables, and data acquisition tools) are well developed from theoretical and practical point of view, they are not widely applied to newly designed or redesigned structures. One of the reasons is the insufficiently established cost-benefit relation, when using such procedures. Consequently, possible clients have to be convinced to use monitoring by pointing out sufficient cost-benefit relation arguments. Today, the cost factor is quite well-known for short and long-term monitoring. Hence, the knowledge about the benefit has to be improved or at least highlighted for the client.

The consideration of cost-benefit relations should be a key point in every practical orientated research program. The arguments may be also strong enough to make such investigations the main content of a separate research project, with the aim to establish and to activate a monitoring lobby in the construction or other industries, like process, chemical, or power industry.

Some ideas are described in the following. Basically, three groups of benefits can be distinguished using monitoring:

1) **Long-term benefits:** Monitoring is used to collect data of the structure, which can be used to control the remaining lifetime of the structure or production unit. Furthermore, the data is helpful during the reassessment process with the aim of a life time extension or change of use of the structure or facility. Costs can be saved in a very late state of the life cycle. There are no benefits during the design phase.
2) **Mid-term benefits:** Monitoring is used to obtain short-, medium-, and long-term data where the current knowledge about load assumptions or resistance is not known or not sufficiently described by current codes and standards. The possible benefit is to improve the assumptions and to reduce uncertainties. If the current assumptions are too conservative, costs can be saved directly in the design phase, if the assumptions are too unsafe failure costs can be saved during the operation phase. It has to be mentioned, that the obtained knowledge is only useful for future projects of similar type. One application is, for example, the recently discussed question about the load assumptions of a crowd, for example, in a stadium or on footbridges. However, a benefit for the client itself can be achieved not earlier than in 10 to 15 years. Such an investigation might be not be of direct interest to the client and should be a topic of research projects.
3) **Short-term benefits:** Monitoring can be integrated as a part of continuous risk assessment, risk control, and risk management. The basic principle is to provide a lower reliability level or a lower basic safety level while the required safety level is achieved by observation and control of the risk. This idea can be followed during the design phase and more beneficially during the redesign phase of the life cycle of the structure, product, or industrial plant. Methods like Bayesian updating have to be proven for this purpose and new methods and strategies have to be developed. The cost reduction even in the design phase is the advantage of such an approach. Monitoring can be beneficial especially for the prevention of events with a low or medium probability of occurrence. Possible application areas are industrial plants, where the leaking of toxic substances can be monitored for example. An alarm can then evacuate the plant. Another application example is the monitoring of the wind speed over bridges. If it is not safe enough to cross the bridge, it will be closed automatically.

In each case an advanced probabilistic short-, medium-, and long-term cost-benefit analysis has to be performed to evaluate the cost-benefit relation of using monitoring. In process industry, for example, the replacement of production units can be more beneficial than achieving a small lifetime extension by monitoring. Other benefits can be obtained by adopting the knowledge of one monitored facility to other similar facilities, for example, for production units in an offshore platform field. It is suggested to perform case studies of realistic structures to show up where monitoring can save costs. The potential clients will increase their interest in monitoring if an amount of saved money can be identified and presented.

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