EACS 2016 Conference

11th -13th July, Sheffield, UK

since 1993 eacs European Association for the Control of Structures

The University Of Sheffield.

Dynamics Research Group

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Dear Delegate,

Welcome to the 6th European Conference on Structural Control (EACS 2016) which is sponsored by the European Association for the Control of Structures. We are delighted to be hosting the EACS conference at the University of Sheffield. In particular we are very pleased to be able to hold the conference in the new Diamond building. For those that are interested, a tour of the Diamond will be available on Wednesday afternoon after the conference sessions finish.

We hope that you enjoy your visit to Sheffield, and are able to see some of the industrial heritage that the city is famous for. Those attending the conference dinner at Cutlers Hall on Tuesday evening will note the close association of the venue with Sheffield's rich industrial past.

It is exciting to see so many papers of interest in the conference programme. There are clearly some new and exciting research themes of great interest to many of the participants. Our intention is to provide a warm and welcoming atmosphere in which these research topics and ideas can be discussed and debated. We hope you will meet friends old and new, and collaborations will flourish.

With warmest regards from the local organising committee,

David Wagg (Conference Chair)

Robert Barthorpe

Lizzy Cross

The following information contains practical guides for delegates attending the EACS 2016 conference, 11-13 July, Sheffield, UK.

If you have any queries about the travel and stay in Sheffield, please do not hesitate to contact any member of us.

Information Regarding the Technical Sessions

Presenters of Contributed Papers

Each oral presentation is allocated 20 minutes, including 15 minutes for presentation and 5 minutes for questions and moving to the next presenter.

Each room will have a data projector and a computer running Windows, with Microsoft Powerpoint and Adobe Reader DC installed. Presentations should be on a USB memory stick. Presenters are asked to upload their presentation before the session starts and to meet the session chair in the room before the session is due to begin. Presenters can load directly onto the computer in the room in which they will be presenting at any time during a break before the presentation.

If a presenter would prefer to use their own laptop, VGA, HDMI port connections will be provided. Please ensure that the laptop is tested with the AV equipment during the break before the start of the session.

Conference Proceeding Files

All PDF files of the papers will be available from the website: http://eacs2016.co.uk/ with the following pass word: **eacs2016**

Wireless Network

Academic users should be able to detect the **EDUROAM** network through their portable device and log in via their home institution.

Others should select the **GUEST** network and use the password: **shefconfkey**

Conference Registration and Venue

Conference Venue

The EACS 2016 conference will take place in the Diamond building, University of Sheffield. Registration desk will be located in the foyer of the Diamond. All keynote lectures and technical sessions will take place in Lecture Theatre 3 and 4 on the basement level of the Diamond.

At the end of the conference, there will be a tour of the Diamond building. Please refer to the map and floor plan sections for more details.

Registration

Early registration will be available in the Diamond foyer between 15:00 to 17:00, Sunday July 10th. Registration desk will be open from 8:00 am, Monday July 11th, please make sure register with us and claim your delegate pack upon your arrival.

Entertainment

Drinks, Refreshments and Lunch

Light refreshments will be provided between 8:30-9:00 each morning during the conference, tea and coffee will be available throughout the day, as well as lunch buffet, between 12:10 and 13:40, on the basement level of the Diamond building.

On Monday July 11th from 17:30, there will be a drinks reception also on the basement level of the Diamond.

Conference dinner will take place in the Cutlers Hall, Church Street, Sheffield, S1 1HG. The dinner will start at 19:00, for map and instructions please refer to the Dinner Venue section.

Local Travel Information

Parking

Parking at the University is extremely limited. It is anticipated that most delegates will walk or take public transport (bus or tram) to the Diamond Building from their accommodation. University car parks cannot be used without a permit. The small amount of local public parking (on-street or in the Rockingham Street Multi-storey Q Car Park S1 4EB adjacent to the University) fills up early and is costly.

Public Transport

Sheffield has a compact city centre with a very good public transport network. The University campus lies just a few minutes' walk to the west of the city centre. The University website gives maps and directions (http://www.sheffield.ac.uk/visitors). From the city centre, bus and tram are the most convenient forms of transport. On the tram take any blue or yellow service towards Middlewood or Malin Bridge and alight at the **West Street** stop. Buses numbers 6, 10, 95, 120, 51, 52 and 52a all stop within a few hundred metres of the venue.

Taxis

For the local taxi service, please dial +44 114 2393939 or use Uber service. 'London black cabs' displaying 'For Hire' can be stopped in the street, but other licensed taxis must be pre-booked.

Foreign Exchange and Banking

The official currency in the UK is the pound sterling. Sheffield is not a major tourist destination and payment in Euros or traveller's cheques is not possible in most shops, though all major international credit cards are accepted in shops, hotels and restaurants. There are limited foreign exchange facilities; the nearest would be NatWest or Barclays banks, Marks & Spencer or Thomas Cook shops on Fargate/Pinstone Street/High Street in the City Centre. Most banks are open weekdays from 9 AM to 5 PM, Saturdays 9AM to 3 or 4 PM. ATMs (Automatic Teller Machines) are available 24/7 and located throughout the city.

Emergency Information

Emergency Situations and Medical Services

In case of emergency call in the UK call 999. These calls are free and no region code is required. The European emergency number 112 can also be used. Within the University, using a university handset, please call 4444 to summon internal, as well as external, assistance.

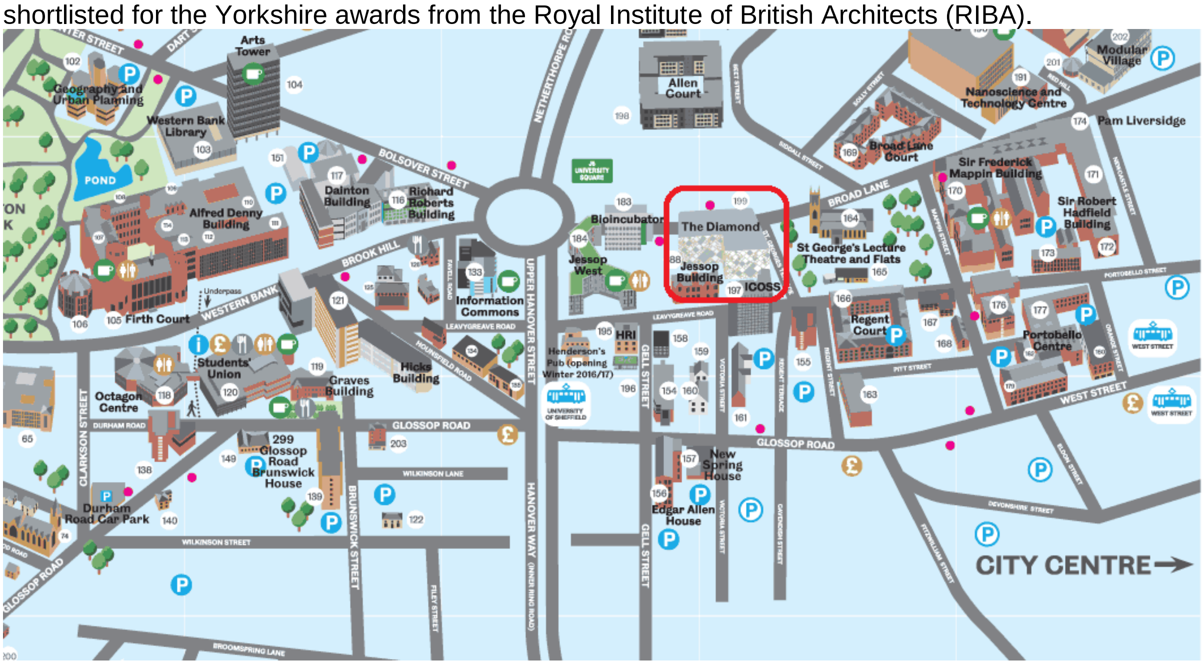
Conference Locations

The Diamond
32 Leavygreave Rd, Sheffield
S3 7RD

There will be a Diamond Tour in the end of the conference, introducing the latest teaching and researching labs and facilities of the Sheffield University. The Tour will start at 4:00 pm, Wednesday, July 13th, if you are interested please stay with us after the last technical session is finished.

The Diamond - at £81 million the University of Sheffield's largest ever investment in teaching and learning – opened its doors to students and staff on September 28th 2015.Construction began on site in 2013 and the project was delivered on time and to budget.

The stunning new building has already created a fantastic place for modern interdisciplinary teaching, generating interest from all over the world. It won the Design through Innovation award in the 2016 Yorkshire and Humber Region Royal Institute of Chartered Surveyors (RICS) awards, and was also shortlisted for the Yorkshire awards from the Royal Institute of British Architects (RIBA).



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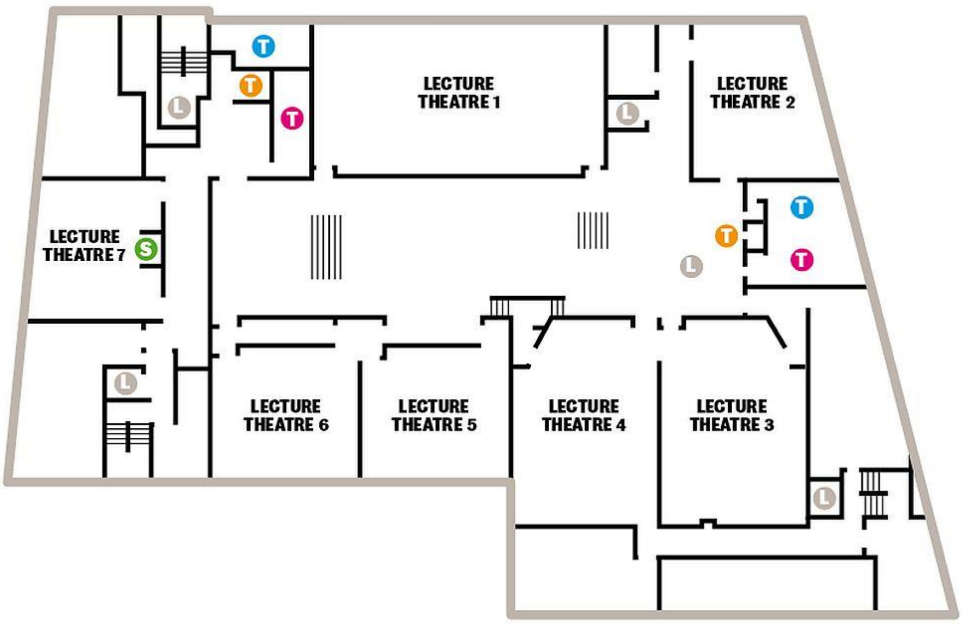
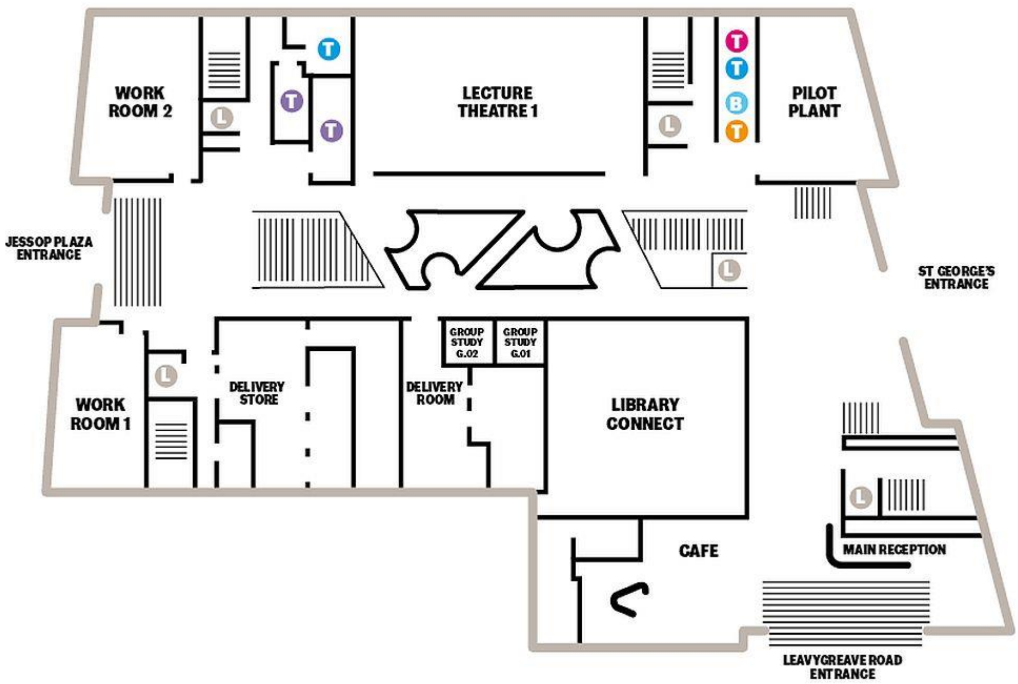
Floor plans:

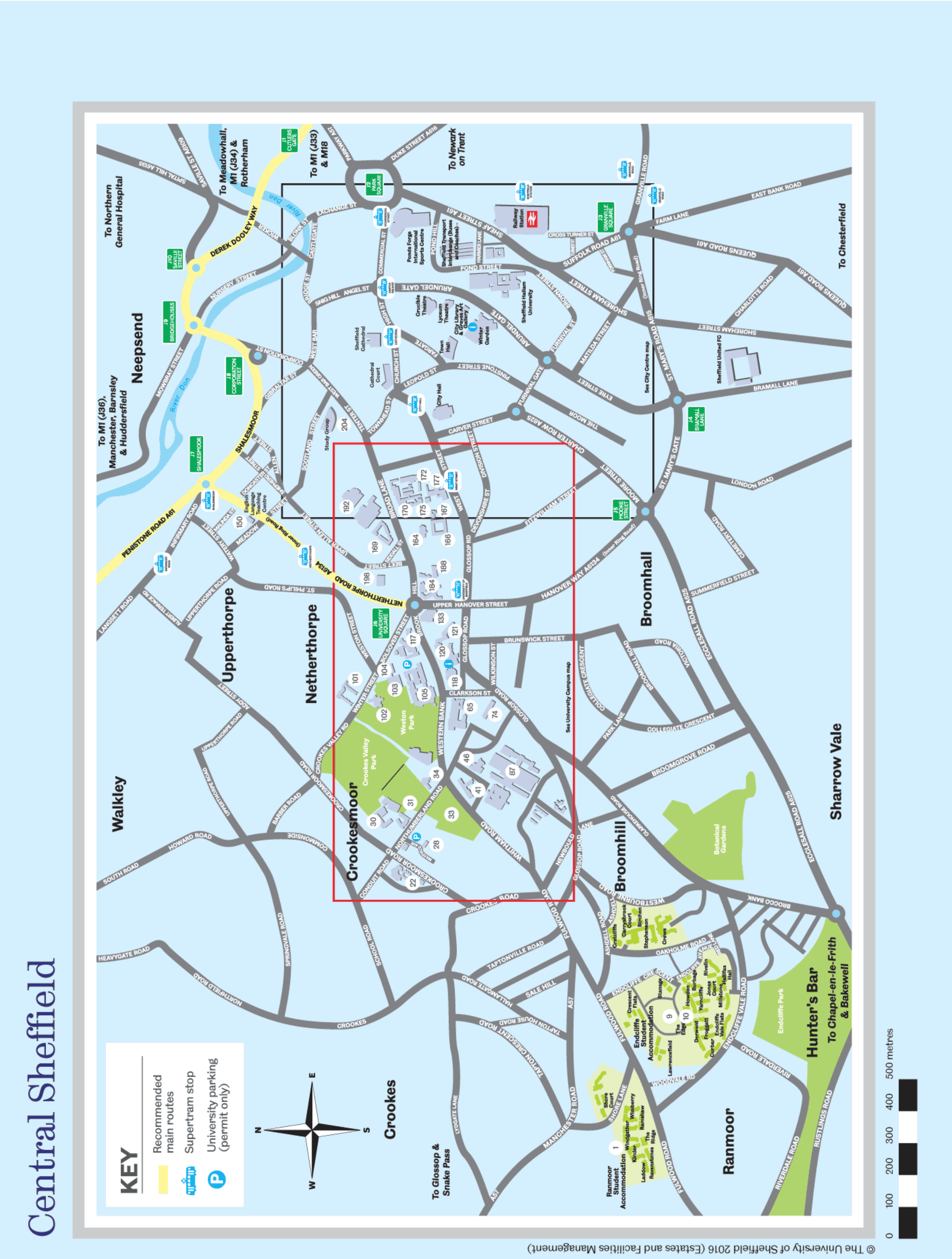
Basement:



Ground Floor:



Sheffield City Centre Map



Sheffield University Campus Map

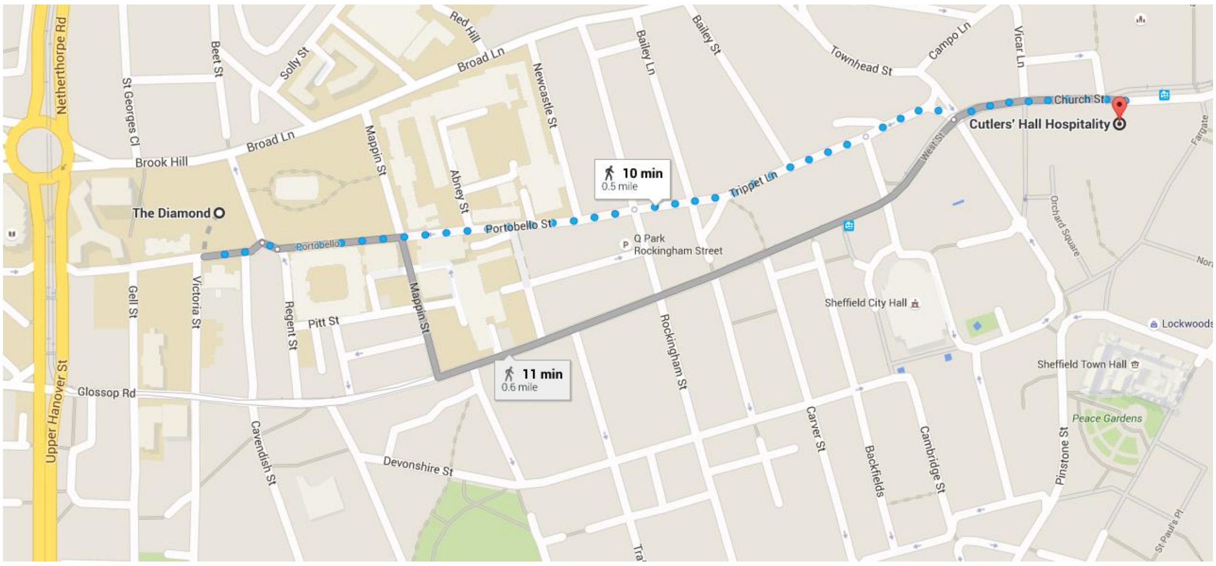
Dinner Venue

Cutlers' Hall

Church Street
Sheffield

S1 1HG

The Cutlers' Hall is right opposite to the Sheffield Cathedral, about 10 minutes' walk distance from the conference venue.



Local Tourist Attractions

1. **Millennium Gallery**

Sheffield's landmark art gallery home to permanent exhibitions in the Ruskin, Metalwork and Craft & Design galleries, as well as touring National exhibitions.

2. **Winter Garden**

The largest urban glass house in Europe One of Sheffield's most iconic buildings, the Winter Garden houses over 2000 species of plants from all around the world.

3. **The Kelham Island Museum**
Showcasing Sheffield's industrial story from early industrialisation to modern times, with Europe's largest working 12,000hp steam engine.

4. **Tropical Butterfly House**
Meet amazing animals from around the world during inspiring close-up encounters; including cheeky Meerkats, Lemurs, Owls, Wallabies, Snakes, birds of prey, & many other creatures!

5. **Sheffield Botanical Gardens**

Originally designed by Robert Marnock in 1836, the garden covers 19 acres with 15 different areas, including plants from all over the world.

6. **New Moor Market**
Opened in November 2013 Sheffield's brand spanking new Moor Market is a foodie haven with over 196 stalls of artisan produce.

7. **The Peak District**

1/3 Sheffield lies in the Peak District boundary where quaint villages, traditional pubs & stunning wide open spaces for a range of outdoor pursuits await.

8. **Chatsworth House**

Known as the 'Palace of the Peak' the lavish home of the Devonshire family and one of Britain's grandest country houses is just a stone's throw from Sheffield.

9. **Sheffield Theatres**

The largest theatre complex outside of London, comprising three theatres- the Crucible, the Lyceum and the Crucible Studio, offering both in-house productions and touring shows.

10. **Sheffield City Hall**
Hosts some the most famous names in entertainment from pop to philharmonic concerts, comedy club to contemporary dance.

Plenary Keynote Lectures

Monday, July 11th, 09:00-10:00, Lecture Theatre 3, Diamond Building

"The Synergy Between Structural Health Monitoring (SHM) and Control: Can SHM Be Cast as a Controls Problem?"

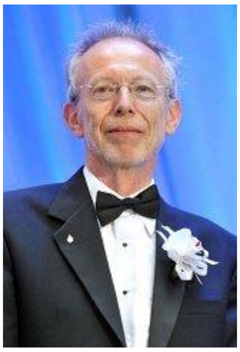
Michael Todd, Professor of Structural Engineering, UC San Diego, USA

Professor Todd's research applies to civil, mechanical, and aerospace structural systems. He focuses on developing tools from structural vibrations, nonlinear dynamics, and time series modeling fields for structural health monitoring and damage prognosis strategies. He also works to develop fiber optic sensor arrays and RFID-enabled sensor networks for making the measurements necessary for initiating such strategies. By integrating these sensor technologies with targeted processing algorithms, Todd is able to create "smart structures" that continually provide data regarding health and performance in an online, efficient manner for optimal decision-making, reconfiguration, performance enhancement, and life safety. Todd's unique ability to combine hardware and software research domains further strengthens the Jacobs School's position as a world leader in integrating large-scale and field testing with computational analysis for purposes of damage diagnostics, damage prognostics, and response modeling of civil, mechanical, and aerospace structural systems.

Michael Todd joined the UC San Diego Structural Engineering Department in 2003. He received Ph.D. (1996) from Duke University's Department of Mechanical Engineering and Materials Science as a National Science Foundation Graduate Research Fellow. In 1996, he began at the US Naval Research Laboratory as an American Society for Engineering Education post-doctoral fellow, where he was later named Section Head (2000) of the Fiber Optic Smart Structures Section until 2003. He has published more than 150 journal papers, conference proceedings, and reports, and holds 4 patents. His main research areas are in structural health monitoring strategies, in fiber optic measurement systems, and in RFID sensor networking for civil infrastructure assessment with UAVs. With partners at Los Alamos National Laboratory, Todd helped create the country's first graduate degree program in structural health monitoring, damage prognosis, and validated simulations at UCSD. Among his many honors, Todd received the 1999 Alan Berman NRL Publication Award, the 2003 and 2004 NRL Patent Award, and the 2005 Structural Health Monitoring Person of the Year award given at the Fifth International Workshop on Structural Health Monitoring. He is a 2004-2005 UCSD Hellman Fellow and a 2005 Von Liebig Entrepreneurship award winner.

Tuesday, July 12th, 09:00-10:00, Lecture Theatre 3, Diamond Building

"Vibration control of large civil engineering structures"



André Preumont, Professor of Mechanical Engineering and Robotics, Université Libre de Bruxelles (ULB), Belgium

André Preumont received his MSc in Aeronautics from the University of Liege in 1973 and his PhD in Applied Sciences in 1981. He spent 10 years in industry before moving in academia. He has been a professor of Mechanical Engineering and Robotics at the Université Libre de Bruxelles (ULB) since 1987, full professor since 1991, and director of the Active Structures Laboratory. He is the author of 7 books. He is a member of the Belgian Royal Academy and was the recipient of the Alexander von Humboldt Research Award in 2011 (Darmstadt, Germany). He was a visiting professor at Virginia Tech (USA), UT Compiègne and INSA Lyon (France), and Politecnico di Milano (Italy). He is a Fellow of the American Institute of Aeronautics and Astronautics. His current researches include Adaptive Optics, Active damping of structures and flapping wing robots.

Wednesday, July 13th, 09:00-10:00, Lecture Theatre 3, Diamond Building

"Control of human-induced vibrations: an integrated approach to vibration serviceability design"

Paul Reynolds, Professor of Structural Dynamics and Control, University of Exeter, UK

Professor Paul Reynolds is a founding director of the Vibration Engineering Section. His current research interests are in the area of control of vibrations caused by human activities on civil engineering structures. To date his work in this area has focused primarily on the use of active vibration control (AVC) of human-induced vibrations in floor structures, which has been supported through a major EPSRC research grant (£616K) entitled "Active Control of Human-Induced Vibration" which commenced on 1st February 2010.

More recently Professor Reynolds was awarded a highly prestigious EPSRC Leadership Fellowship (£1,057k) entitled "Advanced Technologies for Mitigation of Human-Induced Vibration" which commenced on 1 October 2011. Throughout this 5 year fellowship Professor Reynolds will focus his efforts full-time into developing a range of advanced vibration mitigation technologies for human-induced vibration problems. This will include passive, active, semi-active and hybrid technologies suitable for the full spectrum of human-induced vibration problems ranging from single pedestrians on floors through to large crowds on sports stadia and large footbridges.

Professor Reynolds is also a regular consultant to industry in vibration serviceability and related areas, including dynamic testing and monitoring of a number of UK sports stadia and examining solutions to the London Millennium Bridge problem. He is also a Director of Full Scale Dynamics Limited, a University spin-off company that was established in 2008.

Conference Schedule Overview

Sunday 10th July: **Early registration in the diamond foyer 15.00-17.00**

	Monday July 11th		Tuesday July 12th		Wednesday July 13th	
8.00-17.00	Registration desk open - Diamond foyer					
8.30-9.00	Welcome - light refreshments					
	Diamond LT3	**Diamond LT4**	**Diamond LT3**	**Diamond LT4**	**Diamond LT3**	**Diamond LT4**
9.00-10.00	Keynote: M. Todd	N/A	Keynote: A. Preumont	N/A	Keynote: P. Reynolds	N/A
10.00-10.30	Coffee Break - Diamond basement					
10.30-10.50	Control 1 (Chair: F Casciati)	Smart materials (Chair: O Ganilova)	Civil SHM (Chair: J Brownjohn)	Earthquake 2 (Chair: V Gattulli)	Active and semi active control (Chair: M Zilletti)	Inerters (Chair: J Holnicki-Szulc)
10.50-11.10						
11.10-11.30						
11.30-11.50						
11.50-12.10						
12.10-13.40	Lunch Buffet - Diamond basement					
13.40-14.00	Control 2 (Chair: J Rodellar)	Earthquake 1 (Chair: C Lord)	SHM 2 (Chair: N. Dervilis)	Earthquake 3 (Chair: A. Giaralis)	Damping (Chair J. Rongong)	Inerters/Active TMD (Chair: S Neild)
14.00-14.20						
14.20-14.40						
14.40-15.00						
15.00-15.20						
15.20-16.00	Coffee Break - Diamond basement					
16.00-16.20	SHM 1 (Chair: C Sbarrufatti)	Tuned mass dampers (Chair: I Lazar)	Hybrid testing (Chair: O Bursi & N Tondini)	System ID and nonlinear systems (Chair: J Mottershead)	**Diamond tours**	
16.20-16.40						
16.40-17.00						
17.00-17.20					**Conference Close**	
Evening	Drinks reception - Diamond basement		Conference Dinner - Cutlers Hall			

Monday 11th July

Plenary Talk, Monday 11th July, 9.00 – 10.00 Location: Lecture Theatre 3, Diamond Building

The Synergy Between Structural Health Monitoring (SHM) and Control: Can SHM Be Cast as a Controls Problem?

Michael Todd

Professor of Structural Engineering, University of California San Diego
La Jolla, CA USA
mdtodd@ucsd.edu

Structural health monitoring (SHM) is the general process of making an assessment, based on appropriate analyses of in-situ measured data, about the current ability of a structural component or system to perform its intended design function(s) successfully. Damage prognosis (DP) extends this process by considering how the SHM state assessment, when combined with probabilistic future loading and failure mode models with relevant sources of uncertainty adequately quantified, may be used to forecast remaining useful life (RUL) or similar performance-level variables in a way that facilitates efficient life cycle management and possibly even suggest mitigation strategies. A successful SHM/DP strategy may enable significant ownership cost reduction through maintenance optimization, performance maximization during operation, and unscheduled downtime minimization, and/or enable significant life safety advantage through catastrophic failure mitigation.

In broad terms, any SHM/DP strategy inevitably must, for a well-defined application, include in-situ data acquisition, feature extraction from the acquired data, statistical modeling of the features, and classification of the features to make risk-informed decisions; the ultimate global goal of SHM/DP systems is to direct economically efficient and/or safety-maximized structural health decision-making for the general purpose of long-term effective life cycle management and damage mitigation. One such paradigmatic approach that integrates these elements is Bayesian experimental design, which that facilitates the design of such a strategy in four steps: (1) Evaluation of the design space including constraints, (2) Extraction of relevant candidate features and modeling their variability as a function of free design variables, (3) Derivation of a detector, and (4) Evaluation of detector performance. This presentation will present this new paradigmatic approach and explore its suitability as being cast as a form of a controls/optimization problem involving plant/state definition, constraints, and feedback.

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Control 1 Location: Lecture Theatre 3, Diamond Building Session Chair: F. Casciati		
Monday 11th July		
Time		Paper #
10.30	**Fault Tolerant Control Design of Floating Offshore Wind Turbines** Rodellar, J., Tutivén, C., Acho, L, Vidal, Y *Universitat Politècnica de Catalunya, Barcelona College of Industrial Engineering, Control Dynamics and Applications Research Group, Comte d'Urgell, 187, Barcelona 08036, Spain*	160
10.50	**Manageable Reactor Pressure Vessel Materials Control Surveillance Programme** Krasikov E. A. *National Research Centre «Kurchatov Institute», 1, Kurchatov sq., 123182 Moscow, Russia*	104
11.10	**MIMO control design including input-output frequency weighting for human-induced vibrations** Xidong Wang*[1], Iván M. Díaz[1], Emiliano Pereira[2] [1]*Universidad Politécnica de Madrid, E.T.S. Ingenieros de Caminos, Canales y Puertos, 28040, Madrid, Spain* [2]*Universidad de Alcalá de Henares, Escuela Politécnica Superior, 28805, Alcalá de Henares (Madrid), Spain*	106
11.30	**Real Time Control of Shake Tables for Nonlinear Hysteretic Systems** Ki P. Ryu, Andrei M. Reinhorn *University at Buffalo, State University of New York, USA*	110
11.50	**Mitigation of the structure response based on inertial shock-absorber** Rami Faraj[1], Jan Holnicki-Szulc[1], Lech Knap[2], Jarosław Seńko[2] [1] *Institute of Fundamental Technological Research, Polish Academy of Sciences, Warsaw, Poland* [2] *Warsaw University of Technology, Faculty of Automotive and Construction Machinery Engineering, Poland*	138

Control 2 Location: Lecture Theatre 3, Diamond Building Session Chair: J. Rodellar		
Monday 11th July		
Time		Paper #
13.40	**Receptance based approach for control of floor vibrations** Donald Steve Nyawako[1], Maryam Ghandchi Tehrani[2], Paul Reynolds[1]	139

	[1]Vibration Engineering Section, College of Engineering, Mathematics and Physical Sciences, *University of Exeter, North Park Road, Exeter, EX4 4QF, UK.* *[2]Institute of Sound and Vibration Research, University of Southampton, Highfield, Southampton, SO17 1BJ, UK.*	
14.00	**Passive driving of the waves induced by a helicopter land-crash** Fabio Casciati [1], Sara Casciati[2] and Lucia Faravelli[1] *[1] DICAR / University of Pavia/ via Ferrata 3, 27100 Pavia, Italy* *[2] DICAR/University of Catania/ piazza Federico di Svevia, 96100, Siracusa, Italy*	141
14.20	**Use of overturning spectra in the performance evaluation of on-off control strategies for rocking objects** Rosario Ceravolo[1], Marica Pecorelli[1], Luca Zanotti Fragonara[2] *[1] Politecnico di Torino, Department of Structural, Building and Geotechnical Engineering, Corso Duca degli Abruzzi, 24 -10129 Turin, Italy* *[2]Cranfield University, School of Aerospace, Transportation and Manufacturing, College Road, Cranfield, MK43 0AL, United Kingdom*	145
14.40	**Control Strategies for an Underwater Geotechnical Drilling System** Aldo G. Arriaga[1], Marcos Arroyo[2], Norma Pérez[1], Marcelo Devincenzi[1] *[1] Igeotest, Borrassà w/n 17600 Figueres, Girona, Spain* *[2]Department of Civil Engineering and Geosciences, Division of Geotechnical Engineering, UPC,* *Barcelona, Spain*	180
15.00	**Revealing of the Wave-Like Process in Kinetics of the Reactor Pressure Vessel Steel Radiation Degradation** Krasikov E. A. *National Research Centre «Kurchatov Institute», 1, Kurchatov sq., 123182 Moscow, Russia*	103

SHM 1 Location: Lecture Theatre 3, Diamond Building Session Chair: C. Sbarufatti		
Monday 11th July		
Time		Paper #
16.00	**Recent Advances on Pseudodynamic Hybrid Simulation of Masonry Structures** G. Abbiati[1], G. Miraglia[2], B. Stojadinovic[1] *[1]Department of Civil, Environmental and Geomatic Engineering (D-BAUG), IBK, ETH Zurich,*	111

	Switzerland *[2]Department of Structural, Geotechnical and Building Engineering (DISEG), Polytechnic of Turin, Italy*	
16.20	**Model-based fatigue prognosis of fiber-reinforced laminates exhibiting concurrent damage mechanisms** M. Corbetta[1], C. Sbarufatti[1], M. Giglio[1], A. Saxena[2], K. Goebel[3] *[1]Politecnico di Milano, Dipartimento di Meccanica, via La Masa 1, Milan 20156, Italy.* *[2]General Electric Global Research, 2623 Camino Ramon Suite 500, San Ramon, CA 94583.* *[3]NASA Ames Research Center, Intelligent Systems Division, MS 269-4, Moffett Field, CA 94035.*	128
16.40	**On Correlation and Causality in Structural Dynamics** E.J. Cross and K. Worden *Dynamics Research Group, University of Sheffield, UK*	167
17.00	**Damage Identification Research of Spatial Structure using wavelet packet energy method Based on Dynamic Strain** Li XU , Jiaqi KUANG *Earthquake Engineering Research & Test Centre, Guangzhou University, Guangzhou 510405, China*	152

Special Session: Smart Materials

Location: Lecture Theatre 4, Diamond Building

Session Chair: O. Ganilova

Monday 11th July

Time		Paper #
10.30	**Vibration Response and Damping Behaviour in Sandwich Composites with Magnetorheological Elastomer Core** Pooja Sharma and Nagendra Gopal, K.V. *Department of Aerospace Engineering, Indian Institute of Technology Madras, Chennai, India*	119
10.50	**Semi-active Vibration Control Using Piezoelectric PZT Composite Films** O. Altay[1], R. Wunderlich[2], S. Klinkel[1] *[1]RWTH Aachen University, Faculty of Civil Engineering* *[2]RWTH Aachen University, Faculty of Electrical Engineering and Information Technology*	124
11.10	**Optimal Tuning Of Shunt Parameters For Lateral Beam Vibration Attenuation With Three Collocated Piezoelectric Stack Transducers** Benedict Götz[1], Oliver Heuss[2], Roland Platz[2] & Tobias Melz[1]	149

	[1]*Technische Universitat Darmstadt, System Reliability and Machine Acoustics SzM, Magdalenenstrasse 4, D-64289, Darmstadt, Germany* [2]*Fraunhofer Institute for Structural Durability and System Reliability LBF, Bartningstrasse 47, D-64289, Darmstadt, Germany*	
11.30	**Fuzzy Control of Three-Degree-of-Freedom Systems using Multiple MR Dampers** Omar M. M. Elmeligy, Maguid H.M. Hassan *The British University in Egypt (BUE)*	115
11.50	**Energy Harvesting based on the Hybridisation of two Smart Materials** Julian S. Gosliga, Dr Olga A. Ganilova *Dynamics Research Group, Department of Mechanical Engineering, University of Sheffield, Mappin Street, Sheffield, S1 3JD, UK*	170

Earthquake 1

Location: Lecture Theatre 4, Diamond Building

Session Chair: C. Lord

Monday 11th July

Time		Paper #
13.40	**Seismic response of high-strength steel moment connections used in special moment frames** Cheng-Chih Chen, Chung-Yao Hsueh, Miao Wang *Department of Civil Eng., National Chiao Tung University, Taiwan*	165
14.00	**Control of structures subjected to earthquake excitation based on non resonance theory** Nikos G. Pnevmatikos[1], George A. Papagiannopoulos[2], George Hatzigeorgiou[3] [1]*Technological Educational Institution of Athens, Department of Civil Engineering, Surveying and* *Geoinformatics, Ag. Spyridonos Str., P.O. 12210 Egaleo-Athens, Greece* [2]*Department of Civil Engineering, University of Patras, GR-26500 Patras, Greece.* [3]*Hellenic Open University, School of Science and Technology, Parodos Aristotelous 18, GR-26335, Patras, Greece.*	112
14.20	**A Practical Design Method for Seismic Strengthening of RC Frames Using Friction-Based Passive Energy Dissipation Devices** Neda Nabid, Iman Hajirasouliha, Mihail Petkovski *Department of Civil and Structural Engineering, The University of Sheffield, Sheffield, UK*	120
14.40	**Dynamic Behaviour of a Seven-Storey Seismically Isolated Building during the 2011 Tohoku Earthquake**	127

	Toshihide Kashima *Building Research Institute, Japan*	
15.00	**Development of Adaptive Rubber Bearings** C. S. Tsai[1], H. C. Su[2], W. C. Huang[1], T. C. Chiang[3] [1]*Department of Civil Engineering, Feng Chia University, Taichung, Taiwan* [2]*Department of Water Resources Engineering and Conservation, Feng Chia University, Taichung,Taiwan* [3]*Earthquake Proof Systems, Inc., Taichung, Taiwan*	134

Tuned Mass Dampers

Location: Lecture Theatre 4, Diamond Building

Session Chair: I. Lazar

Monday 11th July

Time		Paper #
16.00	**Optimal Design And Practical Implementation Of Eddy-Current Tuned Mass Dampers with Permanent Magnets For Multi-Storey Buildings** Álvaro Magdaleno[1], Emiliano Pereira[2], Javier Castaño[3], Norberto Ibán[3], Iván M. Díaz[4] & Antolín Lorenzana,[1] [1]*ITAP, EII, Universidad de Valladolid, 47011, Valladolid, Spain* [2]*EPS, Universidad de Alcal´a, 28805, Alcal´a de Henares (Madrid), Spain* [3]*Centro Tecnol´ogico CARTIF, 47151, Boecillo (Valladolid), Spain* [4]*ETSICCP, Universidad Polit´ecnica de Madrid, 28040, Madrid, Spain*	174
16.20	**Application and Testing of Hybrid Mass Dampers for Vibration Control of Canton Tower** Ping Tan, Yanhui Liu, Fulin Zhou, Shi Huan *Earthquake Engineering Research & Test Center, Guangzhou University, Guangzhou, 510405, P.R. China*	171
16.40	**Simulation of the response of a lively footbridge under pedestrian loading with two tuned mass dampers for its two first modes (2.1Hz and 2.5Hz)** Norberto Ibán[1], Javier Castaño[1], Álvaro Magdaleno[2], Mariano Cacho[2], Alberto Fraile[3], Antolín Lorenzana[2] [1]*Fundación CARTIF, Parque Tecnológico de Boecillo, Boecillo (Valladolid), Spain* [2]*ITAP. EII. Universidad de Valladolid, Valladolid, Spain* [3]*UPM, Escuela Técnica Superior de Ingenieros Industriales, Madrid, Spain*	182
17.00	Feasiblity Of Viscous Mass Damper With Bingham Fluid Origined Force Restriction Mechanism For Base-Isolated Structure *Masahiro IKENAGA[1], Kohju IKAGO[2] and Norio INOUE[1]* [1]Dept. of Architecture and Building Science, Graduate School of Eng., Tohoku	144

	University, Dr. Eng. [2]International Research Institute of Disaster Science, Tohoku Univ. Dr. Eng.	

Tuesday 12th July

Plenary Talk, Tuesday 12th July, 9.00 – 10.00 Location: Lecture Theatre 3, Diamond Building
Vibration control of large civil engineering structures

André Preumont

Professor of Mechanical Engineering and Robotics
ULB, Active Structures Laboratory Brussels, Belgium
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Large civil engineering structures are sensitive to vibrations due to various excitationssources such as earthquakes, wind, traffic or pedestrians. These vibrations may induce a catastrophic failure of the structure as in the case of earthquake or flutter instability (e.g. Takoma bridge), or they can affect the comfort of the occupants(e.g. wind induced sway of high rise buildings). They may result from a fairly complicated interaction between the structural motion and its environment which necessitates multiphysics tools for their analysis (e.g. in flutter, the structural vibration is the source of unsteady aerodynamic forces). In other cases, they result from the nonlinear behaviour of the structure itself (e.g. parametric excitation of stay cables due to the deck motion of cable-stayed bridges). In some circumstances, pedestrian bridges may be subjected to the phenomenon of synchronization according to which the bridge motion induces the crowd marching on the bridge to synchronize their steps (it was the case in the Millenium bridge in London on the inauguration day). Large bridges are often more sensitive during the construction phase. As the structures tend to become ever larger with time and metallic structures have very little damping, vibration phenomena tend to become more and more important and necessitate special engineering devices to mitigate them and reduce the resonance peaks. Because of their size and the requirements in terms of reliability and serviceability, the actuators play a critical role in the active control loop.

This paper reviews various vibration mechanisms and various vibration control devices which have been used successfully (mostly in the Far-East), and explores some new applications where vibration control could be applied successfully.

Special Session: Civil SHM

Location: Lecture Theatre 3, Diamond Building

Session Chair: J. Brownjohn

Tuesday 12th July

Time		Paper #
10.30	**Advanced Methodologies and Techniques for Monuments Preservation: the Trajan Arch in Benevento as a Case of Study** Luigi Petti[1], Fabrizio Barone[2], Angelo Mammone[1], Gerardo Giordano[3], A.Di Buono[1] *[1] University of Salerno, Dept. of Civil Engineering, Via Giovanni Paolo II, 132, I-84084 Fisciano.* *[2] University of Salerno, Dept. of Medicine and Surgery, Via S. Allende, I-84081 Baronissi (SA).* *[3] University of Salerno, Via S. Allende, I-84081 Baronissi (SA).*	125
10.50	**HIL model and cable stayed footbridge monitoring/control** Fabio Casciati[1], Sara Casciati[2], Lucia Faravelli[1] *[1] DICAR / University of Pavia/ via Ferrata 3, 27100 Pavia, Italy* *[2] DICAR/University of Catania/ piazza Federico di Svevia, 96100 Pavia, Italy*	140
11.10	**Improving Emergency Response Using Wearable Wireless Sensor Networks and Structural Health Monitoring Systems** Sheikhi, E.[1], Cimellaro, G.P.[2] & Mahin, S.[3] *[1]Department of Control and Computer Engineering (DAUIN), Politecnico di Torino, Italy* *[2]Department of Structural, Building and Geotechnical Eng. (DISEG), Politecnico di Torino, Italy* *[3]Department of Civil and Environmental Engineering, University of California Berkeley, USA*	158
11.30	**A new approach to identification of cracks in beams and experimental verification** Chuanchuan Hou, Yong Lu *Instutute for Infrastructure and Environment, School of Engineering, the University of Edinburgh, Edinburgh EH9 3JL, UK*	168
11.50	**Viability of optical tracking systems for monitoring deformations of a long span bridge** James Brownjohn[1], David Hester[2], Yan Xu[1] Bassitt J[1], Koo K-Y[1] *[1] University of Exeter* *[2]Queen's University Belfast*	172

SHM 2 Location: Lecture Theatre 3, Diamond Building Session Chair: N. Dervilis		
Tuesday 12th July		
Time		Paper #
13.40	**Sensor Selection Based On Principal Component Analysis For Fault Detection In Wind Turbines** Pozo, F. & Vidal, Y *Control, Dynamics and Applications (CoDAlab), Department of Mathematics, Escola Universit`aria d'Enginyeria T`ecnica Industrial de Barcelona (EUETIB), Universitat Polit`ecnica de Catalunya (UPC), Comte d'Urgell, 187, 08036 Barcelona, Spain*	175
14.00	**Quantification Of Uncertainty For Experimentally Obtained Modal Parameters In The Creation Of A Robust Damage Model** Gardner, P, Barthorpe, R & Lord, C *Dynamics Research Group, Department of Mechanical Engineering, University of Sheffield, Mappin Street, Sheffield, UK, S1 3JD*	191
14.20	**Design criteria for structural monitoring system: a preliminary approach** V. Gattulli[1], F. Potenza[1], F.J. Baeza[2] *[1]Dep. of Civil, Architectural and Environmental Engineering, University of L'Aquila, Italy* *[2]Dep. of Civil Engineering, University of Alicante, Spain*	197
14.40	**Tool wear state clustering in milling based on recorded acoustic emission** N. Ray[1], E.J. Cross[1], K. Worden[1], S. Turner[2] and J.P. Villain-Chastre[3] *[1] Dynamics Research Group, Department of Mechanical Engineering, University of Sheffield, Mappin Street, Sheffield, UK, S1 3JD* *[2] AMRC, University of Sheffield* *[3] Messier-Bugatti-Dowty*	201
15.00	**Features of Nonlinear Vibration-Based Structural Health Monitoring** Mohamed S. Eid[1], Ayman H. H. Khalil[2] *[1] STRUCTURE International Consultancy Centre, Abu Dhabi, United Arab Emirates* *[2] Structural Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt*	193

Special Session: Hybrid Testing Location: Lecture Theatre 3, Diamond Building Session Chair: O Bursi & N Tondini		
Tuesday 12th July		
Time		Paper #
16.00	**Hybrid simulation applied to fire testing: a newly conceived partitioned static solver** Nicola Tondini[1], Giuseppe Abbiati[2], Luca Possidente[1] and Bozidar Stojadinovic[2] *[1]Department of Civil, Environmental and Mechanical Engineering, University of Trento, Via Mesiano, 38123, Trento, Italy* *[2]Department of Civil, Environmental and Geomatic Engineering (D-BAUG), IBK, ETH Zurich, WolfgangPauli-Strasse 27, Switzerland*	121
16.20	**A comparison of online and offline experimental substructuring methods for the simulation of complex linear dynamic systems.** Oreste S. Bursi[1], Vincenzo La Salandra[1], Giuseppe Abbiati[2], Luca Caracoglia[3] *[1]Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy.* *[2]Department of Civil, Environmental and Geomatic Engineering (D-BAUG), IBK, ETH Zurich, Switzerland.* *[3]Department of Civil and Environmental Engineering, Northeastern University, Boston, Massachusetts, 02115 USA.*	122
16.40	**A Novel Methodology for Hybrid Fire Testing** Ana Sauca[1], Thomas Gernay[1], Fabienne Robert[2], Nicola Tondini[3], Jean-Marc Franssen[1] *[1]University of Liege, Department ArGEnCo, Liege, Belgium* *[2]CERIB, Fire Testing Center, Epernon, France* *[3]University of Trento, Department of Civil, Environmental and Mechanical Engineering, Italy*	132
17.00	**A Pseudodynamic Testing Algorithm for Obtaining Seismic Responses of Structures** Shuenn-Yih Chang[1], Chiu-Li Huang[2] *[1]National Taipei University of Technology* *[2]Fu Jen Catholic University*	135

Earthquake 2 Location: Lecture Theatre 4, Diamond Building Session Chair: V. Gattulli		
Tuesday 12th July		
Time		Paper #
10.30	**Networked Overlapping Control For Building Benchmark** Bakule, L., Papík, M. & Rehák, B. *Institute of Information Theory and Automation, Czech Academy of Sciences, 182 08 Prague, Czech Republic*	142
10.50	**Seismic test of building floor isolation using polynomial friction pendulum isolators** Lyan-Ywan Lu[1], Liang-Wei Wang[1], Chun-Chung Tsai[2] *[1] Department of Civil Engineering, National Cheng Kung University, 1 University Road, Tainan 701, Taiwan* *[2] National Kaohsiung First University of Science and Technology, Kaohsiung, Taiwan*	143
11.10	**Modelling the Response of Isolation Rubber Bearings with Variable Axial Loading** M. Domaneschi[1], L. Martinelli[1], C. Cattivelli[2] *[1]Department of Civil and Environmental Engineering, Politecnico di Milano, Milan, Italy* *[2] Politecnico di Milano*	147
11.30	**Experimental Study Of The Effectiveness Of Semi-Actively Implemented Power-Law Damping On Suppressing The Seismic Response Of A Base-Isolated Building** Maki DAN[1],Masashi OMURA[1],Fumito NAKAMICHI[1],Masayuki KOHIYAMA[1],& Zi-Qiang LANG[2] *[1]Graduate School of Science and Technology, Keio University, Hiyoshi 3-14-1, Kohoku-ku, Yohokohama-shi, Kanagawa, Japan* *[2]Department of Automatic Control and Systems Engineering, The University of Sheffield, Mappin Street, Sheffield, United Kingdom*	155
11.50	**Application of Crescent-Shaped Brace passive resisting system in multi-storey frame structures** *Omar Kammouh[1], Stefano Silvestri[2], Michele Palermo[2], Gian Paolo Cimellaro[1],* *[1]Politecnico di Torino* *[2]University of Bologna*	157

Earthquake 3 Location: Lecture Theatre 4, Diamond Building Session Chair: A. Giaralis		
Tuesday 12th July		
Time		Paper #
13.40	**Modelling the Axial Response of the Roll-N-Cage Device for Seismic Isolation** M. Colombo[1], M. Domaneschi[1], M. Ismail[2], L. Martinelli[1], J. Rodellar[3] *[1]Department of Civil and Environmental Engineering, Politecnico di Milano, Milan, Italy* *[2]Structural Engineering Department, Zagazig University, Zagazig, Egypt* *[3]Departament de Matemàtiques, Universitat Politècnica de Catalunya, Barcelona, Spain*	163
14.00	**Multi-hazard Mitigation of Building Structures using New Floor Isolation Techniques** Hussam Mahmoud and Akshat Chulahwat *Civil and Environmental Engineering, Colorado State University, Fort Collins, CO*	179
14.20	**Fuzzy-sliding mode supervisory control of an electric seismic shake table** Mehdi Soleymani[1] and Amir Hossein Abolmasoumi[2] *[1]Mechanical Engineering Department, Arak University, Arak, 65183-5-5638, Iran* *[2]Electrical Engineering Department, Arak University, Arak, 65183-5-5638, Iran*	187
14.40	**Performance evaluation of a filter-based pseudo-negative stiffness control for seismically isolated structures** Wei Gong, Shishu Xiong *School of Civil Engineering and Mechanics, Huazhong University of Science and Technology, Wuhan 430074, Hubei, PR China*	196
15.00	**Experimental and numerical assessment of a three storey reinforced concrete building submitted to torsion** Pierre-Etienne Charbonnel, Benjamin Richard, Stefano Cherubini *CEA, Seismic Mechanics Laboratory - TAMARIS experimental facility, 91191 Gif-sur-Yvette Cedex, France*	188

System ID and nonlinear systems Location: Lecture Theatre 4, Diamond Building Session Chair: J. Mottershead		
Tuesday 12th July		
Time		Paper #
16.00	**Unscented Kalman filter for simultaneous identification of structural parameters and unknown excitations of a building structure** Hongjun Liu, Qin Huang *Shenzhen Graduate School, Harbin Institute of Technology, Shenzhen, Guangdong, China*	107
16.20	**Parameter Identification of Hysteresis Using Duffing-Like Model** Yuan-Che Chien, Tsu-Yun Cheng, Jia-Ying Tu *Department of Power Mechanical Engineering National Tsing Hua University Hsinchu City, Taiwan (R.O.C.)*	166
16.40	**Mathematical and numerical evaluation of the damping behaviour for a multi-strand bar** Haval Asker, Jem Rongong, Charles Lord *Dynamics Research Group, University of Sheffield,*	202
17.00		

Wednesday 13th July

Plenary Talk, Wednesday 13th July, 9.00 – 10.00 Location: Lecture Theatre 3, Diamond Building

Control of human-induced vibrations: an integrated approach to vibration serviceability design

Paul Reynolds

Professor of Structural Dynamics and Control
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The civil engineering structures of tomorrow will be lighter and more slender than ever before. This is an inexorable trend resulting from architectural desires and the need for future society to use raw materials in an ever more sustainable way. Unfortunately, history has shown us that light and slender civil engineering structures can be highly susceptible to vibrations caused by human activities. Fixing these problems can prove to be extremely difficult, expensive and disruptive and often involves significant structural modifications.

This talk presents some of the recent advances that have been made in the development of advanced vibration control technologies to reduce the adverse effects of human dynamic loading on structures. These technologies have the capacity not only to fix problems when they occur, but may serve to drive a new generation of high performance, efficient and sustainable civil engineering structures by incorporating vibration control technologies into their fundamental vibration serviceability design.

Active and Semi Active Control Location: Lecture Theatre 3, Diamond Building Session Chair: M. Zilletti		
Wednesday 13th July		
Time		Paper #
10.30	**A Method For Computation Of Realizable Optimal Feedback For Semi-Active Controlled Structures** I. Halperin[1], G. Agranovich[1] & Y. Ribakov[2] *[1]Department of Electrical and Electronics Engineering, Faculty of Engineering, Ariel University, Ariel, 40700, Israel,* *[2]Department of Civil Engineering, Faculty of Engineering, Ariel University, Ariel, 40700, Israel*	118
10.50	**Active control of a non-smooth nonlinear system using feedback linearisation** Domenico Lisitano[1], Shakir Jiffri[2], Elvio Bonisoli[1] and John E Mottershead[2] *[1]Dipartimento di Produzione, Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129 Torino, Italy* *[2]Centre for Engineering Dynamics, University of Liverpool, Liverpool L69 3GH, UK*	148
11.10	**LQR–UKF Semi–Active Control Of Uncertain Structures** Dertimanis, V.K.[1], Chatzi, E.N.[1] & Weber, F.[2] *[1]ETH Zurich, Institute of Structural Engineering, Department Of Civil, Environmental and Geomatic Engineering, 8093 Zurich, Switzerland* *[2]Maurer Switzerland GmbH, 8032 Zurich, Switzerland*	161
11.30	**A semi-active rocking system for wind turbines under extreme wind loads** Nicola Caterino[1], Christos T. Georgakis[2], Mariacristina Spizzuoco[3], Antonio Occhiuzzi1[4] *[1] Department of Civil Engineering, University of Naples "Parthenope", Italy* *[2] Department of Civil Engineering, Technical University of Denmark (DTU), Denmark* *[3] Department of Structures for Engineering and Architecture, University of Naples Federico II, Italy* *[4] Construction Technologies Institute, Italian National Research Council (CNR), Italy*	189
11.50		

Special Session: Damping Location: Lecture Theatre 3, Diamond Building Session Chair: J. Rongong		
Wednesday 13th July		
Time		Paper #
13.40	**Electromechanical pendulum for vibration control and energy harvesting** Michele Zilletti, Stephen J. Elliott, Maryam Ghandchi Tehrani *University of Southampton, Institute of Sound and Vibration Research, SO17 1BJ Southampton, UK*	102
14.00	**Analysis of multiple-degree-of-freedom systems containing multi-functional friction damper** Chia-Shang Chang Chien, Wun-Syuan Huang, Yu-Ping Cheng *Department of Civil Engineering and Engineering Management ; National Quemoy University; 1 University Road; Jinning; Kinmen 892; Taiwan.*	116
14.20	**Experimental Study on the Application of Electro-Adhesive Gel Dampers to Base-Isolated Building Using a Small-Scale Specimen** Masashi OMURA[1], Masayuki KOHIYAMA[1], Yasuhiro KAKINUMA[1], Hidenobu ANZAI[2] [1]*Graduate School of Science and Technology, Keio University* [2]*Fujikura Kasei Co., Ltd.*	153
14.40	**Prestressing for local isolation of forced vibrations** Grzegorz Suwała[1], Lech Knap[2], Jan Holnicki-Szulc[1] [1]*Institute of Fundamental Technological Research, IPPT-PAN, Warsaw, PL* [2] *Institute of Vehicles, Faculty of Automotive and Construction Machinery Engineering, WUT, Warsaw, PL*	154
15.00	**Damping Of Metallic Wool With Embedded Rigid Body Motion Amplifiers** Charles E. Lord, Jem A. Rongong, and Ning Tang *University of Sheffield, Department of Mechanical Engineering, Sir Frederick Mappin Building, Mappin Street, Sheffield, S1 3JD, United Kingdom*	198

Inerters Location: Lecture Theatre 4, Diamond Building Session Chair: J. Jolnicki-Szulc		
Wednesday 13th July		
Time		Paper #
10.30	**Investigation Into The Effect Of Device Nonlinearity In Tuned-Inerter-Dampers** Lazar, IF, Gonzalez-Buelga, A & Neild, SA *Department of Mechanical Engineering, University of Bristol, Queen's Building, University Walk, BS8 1TR, Bristol, UK*	105

10.50	**Control of across-wind vortex shedding induced vibrations in tall buildings using the tuned mass-damper-inerter (TMDI)** Francesco Petrini[1], Agathoklis Giaralis[2] *[1] Sapienza University of Rome, Rome, ITALY* *[2] Department of Civil Engineering, City University London, London, UK*	126
11.10	**Passive Vibration Suppression Using Multiple Inerter-Based Devices For A Multi-Storey Building Structure** S.Y. Zhang, T.D. Lewis, J.Z. Jiang & S.A. Neild *Department of Mechanical Engineering, University of Bristol, UK*	146
11.30	**A fluid inerter with variable inertance properties** D. Wagg *Dynamics Research Group, University of Sheffield*	199
11.50	**Resonant Inerter Based Absorbers for a Selected Global Mode** Steen Krenk *Department of Mechanical Engineering, Technical University of Denmark, DK-2800 Lyngby, Denmark*	194

Interters/Active TMD Location: Lecture Theatre 4, Diamond Building Session Chair: S. Neild		
Wednesday 13th July		
Time		Paper #
13.40	**Shaking Table Tests of Cooperative Control between an Active Mass Damper for a Building and Semi-Active Damper for a Base-Isolated Floor Using a Small-Scale Specimen** Fumito NAKAMICHI, Masayuki KOHIYAMA *Graduate School of Science and Technology, Keio University, Yokohama, Japan*	136
14.00	**Robust reliability-based design of seismically excited tuned mass-damper-inerter (TMDI) equipped MDOF structures with uncertain properties** Agathoklis Giaralis[1], Alexandros Taflanidis[2] *[1]Dept. of Civil Eng., City University London, London, UK* *[2]Dept. of Civil and Environmental Eng. and Earth Sciences, University of Notre Dame, Notre Dame, IN,USA*	150
14.20	**Performance Assessment Of A Novel Energy Harvesting-Enabled Tuned Mass-Damper-Inerter (EH-TMDI) For White Noise-Excited Structures** Salvi, J., Giaralis, A. *Department of Civil Engineering, City University of London, Northampton Square, London EC1V 0HB, UK*	151

14.40	**Investigation of Size Effect on Control Performance of Tuned Liquid Dampers by using Real-Time Hybrid Simulation** Fei Zhu, Jin-Ting Wang, Feng Jin, Li-Qiao Lu *State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing 100084,*	114
15.00		

Poster Session

The poster session will take place during lunch time, on Basement Level, Diamond Building, all delegates are welcome to communicate with the presenters.

Title	Author(s)	Affiliation
Damping from Fibrous and Lamellar Microstructures	H. Asker, J. Rongong, C. Lord	Dynamics Research Group, University of Sheffield
Vibration Control Using Tangles Metal Wire Dampers	K. Chandrasekhar, J. Rongong, E. Cross	Dynamics Research Group, University of Sheffield
Structural Health Monitoring: Operational Loading Variations in Vibration Based Damage Detection	S. A. Rahim, G. Manson, K. Worden	Dynamics Research Group, University of Sheffield
Vibration Control for Rigid Structure	N. Tang, J. Rongong, N. Sims	Dynamics Research Group, University of Sheffield
Nonlinear Passive Redesign	X. Liu, D. Wagg, R. Barthorpe	Dynamics Research Group, University of Sheffield
The Development of Symbolic Computational Dynamics Solvers	N. Motazedi, M. Cartmell, J. Rongong, E. Cross	Dynamics Research Group, University of Sheffield
A Nonlinear Cointegration Approach with Applications on Structural Health Monitoring	H. Shi, E. Cross, K. Worden	Dynamics Research Group, University of Sheffield
Performance and Health Monitoring of Gas Turbines	I. Matthaiou, I. Antoniadou	Dynamics Research Group, University of Sheffield
LVV and Engineering Nonlinearity	D. Wagg	Dynamics Research Group, University of Sheffield
A Time Series Decomposition Approach for Structural Health Monitoring of the Tamar Bridge	I. Iakovidis, E. Cross, G. Manson	Dynamics Research Group, University of Sheffield

Abstracts

Control 1

Location: Lecture Theatre 3, Diamond Building

Session Chair: F. Casciati

Monday 11th July

Fault Tolerant Control Design of Floating Offshore Wind Turbines

Rodellar, J., Tutivén, C., Acho, L, Vidal, Y

Universitat Politècnica de Catalunya, Barcelona College of Industrial Engineering, Control Dynamics and Applications Research Group, Comte d'Urgell, 187, Barcelona 08036, Spain

ABSTRACT

This work is concerned with active vibration mitigation in wind turbines (WT) but not through the use of specifically tailored devices. Instead, a general control scheme is designed for torque and pitch controllers based on a super-twisting algorithm, which uses additional feedback of the fore-aft and side-to-side acceleration signals at the top of the WT tower to mitigate the vibrational behavior. In general, proposed methods to improve damping through pitch and torque control suffer from increased blade pitch actuator usage. However, in this work the blade pitch angle is smoothed leading to a decrease of the pitch actuator effort, among other benefits evidenced through numerical experiments. The most frequent faults induce vibrations in the corresponding WT subsystems. In fact, vibration monitoring has been recently used for fault diagnosis Thus, by means of vibration mitigation, different faulty conditions can be alleviated leading to a passive fault tolerant control. In this work, coupled non-linear aero-hydro-servo-elastic simulations of a floating offshore wind turbine are carried out for one of the most common pitch actuator faults.

Keywords: *wind turbine, vibration mitigation, super-twisting algorithm*

Manageable Reactor Pressure Vessel Materials Control Surveillance Programme

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ABSTRACT

As a main barrier against radioactivity outlet reactor pressure vessel (RPV) is a key component in terms of safety and extended light water reactor (LWR) life. The surveillance programme (SP) calls upon to predict ahead RPV materials characteristics conservatively to guarantee RPV structural integrity without any compromise. General vice of existing SPs is an impossibility of SP changing and development during reactor operation (30, 60 and even more years). Up to day, approach based on initial hard nomenclature of surveillance specimens installed in capsules. Therefore, practically it is impossible to change anything in SP during RPV service life. Anachronistic principle of ahead of time, for some decades of years in advance fabrication and installation into reactor vessel the sets of surveillance specimens (SS) contradicts to request of RPV innovative monitoring technologies development during long-term operation.

Besides there is a deficiency of SP portliness relative to conditions of the RPV irradiation during operation. Most important is the discrepancy of the actual thermal condition of RPV wall from SSs irradiation temperature. This fact carries in the element of non-conservatism into the system of control. Ideally, surveillance metal has to be irradiated in contact with coolant. Metal placement in perforated capsules that is immediately in running water provides the minimum irradiation temperature and therefore guarantees the most conservative data on RPV metal mechanical properties getting. Clearly, that at this case there is no need in temperature monitors. Moreover, today there is no hard confidence in SS capsules integrity during RPV operation. In the event of capsule depressurization SSs damage occurs. At the same time in reality it is impossible to exclude environmentally assisted cracking of the primary circuit stainless steel components during 60 and more years of operation. Surveillance metal contacting with water in perforated capsules emulate RPV metal-water corrosion reaction appearance as a result of possible cladding cracking and hydrogen (as a corrosion product) - metal interaction. Therefore for materials susceptible to hydrogen embrittlement, the degree of SP conservatism grows.

We suggest to improve LWR SPs by means of passage from existing «hard» SPs to «flexible» manageable SPs (MSP) that would give the possibility of SP adaptation to requirements of time and to strengthen technical and scientific potential of investigators and researchers in the future. So, we believe that is no sense to leave present-day level of knowledge and technology in congeal state to next generation of researchers. Thus for new LWRs with the service life of 60 and more years we propose pass on from the SSs of routine nomenclature to MSP i.e. sets of archive materials coupons placed in non-hermetic containers and cooled directly by running water. It gives a perspective in case of need put into practice an innovative MSP taking into account the state-of-the-art safety standards, technical progress, present day level of science and technology.

In support of the above-mentioned MSP conception 5 year duration prototype version of the MSP is under execution at operating commercial LWR.

MIMO control design including input-output frequency weighting for human-induced vibrations

Xidong Wang*[1], Iván M. Díaz[1], Emiliano Pereira[2]

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[2]*Universidad de Alcalá de Henares, Escuela Politécnica Superior, 28805, Alcalá de Henares (Madrid), Spain*

ABSTRACT

Civil structures such as floors with open-plan layouts or lightweight footbridges can be susceptible to excessive levels of vibrations caused by human activities. Active vibration control via inertial-mass actuators is a viable technique to mitigate vibrations, allowing structures to satisfy vibration serviceability limits. Recently, a multi-input multi-output active vibration control technique has been proposed by the authors. This technique finds simultaneously the sensor/actuator pairs' optimal placements and the control gains, where direct velocity feedback is considered. Issues such as actuator dynamics, high-pass filters and low-pass filters were considered for the practicality of the technique. This paper introduces new elements such as input-output frequency weighting in order to take into account the frequency nature of human loading and human perception, respectively. Simulation results on a rectangular floor model and time domain tests have been carried out to confirm the improvements.

Keywords: *Active vibration control, Human-induced vibrations, Optimal control, Inertial-mass actuators, Floor vibrations*

Real Time Control of Shake Tables for Nonlinear Hysteretic Systems

Ki P. Ryu, Andrei M. Reinhorn

University at Buffalo, State University of New York, USA

ABSTRACT

Shake table testing is an important tool to challenge integrity of structural and non-structural specimens by imposing excitations at their base. When shake tables are loaded with specimens, the interaction between the tables and specimens influence the system dynamics that result in undesired performance. Open loop feedforward compensation methods have been used successfully in current practice of table controls, assuming that the specimens remain linear. However, unsatisfactory signal performances were observed when flexible and heavy specimens experience nonlinear behavior. While lack of high fidelity might be acceptable for the purpose of exploration of specimens subjected to random excitations, a high fidelity of signal reproduction is necessary for shake table qualification testing where specific target motion is required to challenge the specimens. A nonlinear tracking control scheme based on the feedback linearization method is proposed for the control of shake tables to simulate target motions at specific locations of the test structures having nonlinear hysteretic behavior. A real-time estimator using the extended Kalman filter combined with the controller is adopted in order to account for the changes and uncertainties in system models due to nonlinearities and yielding. The proposed adaptive tracking control method is applied in numerical simulations to a setup of a realistic shake table testing of a nonlinear structure.

Keywords: *Shake table test, Nonlinear hysteretic system, Adaptive control, Real-time parameter estimation.*

Mitigation of the structure response based on inertial shock-absorber

Rami Faraj[1], Jan Holnicki-Szulc[1], Lech Knap[2], Jarosław Seńko[2]

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ABSTRACT

The goal of this paper is to present further development of the inertial shock-absorber called SPIN-MAN. Application of the device in mitigation of structures response is investigated and selected case study is discussed. The specific construction and operation of the device is introduced and explained. In reference to the impact absorption problems, the SPIN-MAN is a concept of adaptive inerter device with two phases of operation. The first of them includes energy absorption and accumulation. External energy of the load is converted to kinetic energy of rotational motion of the mass. During the second phase, accumulated energy is dissipated by inverse spinning of the second mass powered by the remaining part of the impact energy. To obtain this type of operation, special switchable actuators are used.

Applicability of the device in mitigation of impact-born structure response, especially in case of space systems, is investigated. General concept of the device construction and operation is adjusted to meet the requirements for space systems. This results in a fluidless, passive-like solution but adaptable to the load conditions. Tuning of the shock-absorber may be realized by manual or easily automated mechanical adjustments. Effectiveness of the solution is based on the specific on/off type of control, which is responsible for the optimal energy flow in the system and efficient dissipation of impact energy inside the SPIN-MAN. Results of numerical simulations confirmed quick and effective operation of this device.

Keywords: *structure response mitigation, adaptive impact absorption, adaptive inerter, semi-active control, shock-absorber.*

Control 2

Location: Lecture Theatre 3, Diamond Building

Session Chair: J. Rodellar

Monday 11th July

Receptance based approach for control of floor vibrations

Donald Steve Nyawako[1], Maryam Ghandchi Tehrani[2], Paul Reynolds[1]

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[2] *Institute of Sound and Vibration Research, University of Southampton, Highfield, Southampton, SO17 1BJ, UK.*

ABSTRACT

Advances in design, materials and construction technologies, coupled with client and architectural requirements are some of the drivers for light-weight and open-plan floor layouts. These are becoming increasingly susceptible to human induced vibrations. The use of active control techniques is progressively being viewed as a more feasible approach for suppressing such vibrations over the passive technologies.

In this paper, the principles of the receptance based approach are exploited to design appropriate feedback gains that place the eigenvalues of an experimental footbridge prototype at selected locations thereby enhancing its vibration mitigation performance. The studies presented here are based on SIMO (1 actuator and 2 sensors) and MIMO (2 sensors and 2 actuators) controller structures that have the potential to offer greater design freedoms beyond purely direct velocity feedback controllers. This work presents the analytical determination of appropriate feedback gains from results of experimental modal analysis (EMA) on the footbridge prototype and thereafter the experimental implementation of these feedback gains on the actual structure. Vibration mitigation performance is evaluated through both changes in measured transfer functions and reductions in response under single pedestrian excitation.

Passive driving of the waves induced by a helicopter land-crash

Fabio Casciati [1], Sara Casciati[2] and Lucia Faravelli[1]

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[2] *DICAR/University of Catania/ piazza Federico di Svevia, 96100, Siracusa, Italy*

ABSTRACT

Infrastructures for helicopter landing, the so called heliports, are becoming more and more common. From a safety point of view, this means a clustering of helicopter trajectories with an increase of accident occurrence at the site. The surrounding buildings are subjected to a spread of vibration waves. The goal of this contribution is to investigate policies for driving these waves far from where they could cause economical losses.

Keywords: *Helicopter, Heliport, Passive control, Soil structure interaction*

Use of overturning spectra in the performance evaluation of on-off control strategies for rocking objects

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ABSTRACT

Rocking of rigid bodies induced by seismic events triggers a number of complex dynamic phenomena such as impacts, sliding, uplift, which can potentially result in disastrous outcomes. Typical structures that present a significant seismic vulnerability with respect to overturning are water tanks, electrical and hospital equipment, statues and art objects. Several methods have been investigated in the past years to prevent the overturning or damage, such as rigid anchorages or base isolation devices.
This paper presents some numerical investigations about a novel on-off adaptive control strategy for rigid blocks subjected to rocking motion. In more detail, control algorithms were specifically conceived to regulate an adjustable stiffness of two restrainers placed at the lower corners of the block. The control's laws and the anchorage devices exhibited good performance when excited by simple one-sine pulse excitation, as reported by the authors in a previous study. The present work will instead investigate the performance and the robustness of the controlled system with respect to amplitude modulated harmonic excitations.

Keywords: *Rigid block, Rocking Motion, Adaptive Control, Non-Linear Response System, Seismic rocking*

Control Strategies for an Underwater Geotechnical Drilling System

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ABSTRACT

Submarine geotechnical exploration is a challenging task that is experiencing a paradigm shift due to the application of robotics and automation to (until now) traditional drilling procedures. The MD500 Project is an underwater subsea geotechnical drilling and in situ testing device developed with the goal of retrieving high-quality physical samples of the seabed at study depths of up to 150 m and with a nominal water depth of 500 m. The system applications range in areas of marine activity, such as: port infrastructure, nearshore and offshore, renewable energy projects at sea, oil & gas, mining etc.
The machine is composed of a set of remotely operated devices that must synchronize with each other: drilling rig, stabilizing legs and three manipulators two Cartesian robots and one anthropomorphic robot arm. These manipulators can be operated either manually or in a semi- automated mode. The automated routines aim to substitute the actions of the technicians when handling the tubes and rods in the harsh environment for which the machine is envisioned, allowing the operator to focus on the drilling process (which can be semi-automated as well). Some other benefits that can be obtained by automating the processes are reduction in cycle times and increased repeatability —which leads to higher efficiency

rates since the cycle times are more consistent and can be predicted more accurately. All these advantages lead to a reduction of the overall operation cost.
In order to accurately control the position of the electro-hydraulic motion systems a set of Fuzzy-Adaptive PID (proportional-integral-derivative) controllers is implemented. The paper presents an overview of the control loops implementation, performance assessment, distributed control network architecture and the logic behind the tool manipulation and the handling sequences and routines of the MD500.

Keywords: *Underwater geotechnics, underwater robotics, fuzzy PID, hydraulic manipulator*

Revealing of the Wave-Like Process in Kinetics of the Reactor Pressure Vessel Steel Radiation Degradation

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ABSTRACT

Influence of neutron irradiation on reactor pressure vessel (RPV) steel degradation are examined with reference to the possible reasons of the substantial experimental data scatter and furthermore – nonstandard (non-monotonous) and oscillatory embrittlement behavior. In our glance this phenomenon may be explained by presence of the wavelike recovering component in the embrittlement kinetics.

We suppose that the main factor affecting steel anomalous embrittlement is fast neutron intensity (dose rate or flux), flux effect manifestation depends on state-of-the-art fluence level. At low fluencies radiation degradation has to exceed normative value, then approaches to normative meaning and finally became sub normative. Data on radiation damage change including through the ex-service RPVs taking into account chemical factor, fast neutron fluence and neutron flux were obtained and analyzed.

In our opinion controversy in the estimation on neutron flux on radiation degradation impact may be explained by presence of the wavelike component in the embrittlement kinetics. Therefore flux effect manifestation depends on fluence level. At low fluencies radiation degradation has to exceed normative value, then approaches to normative meaning and finally became sub normative. As a result of dose rate effect manifestation peripheral RPV's zones in some range of fluencies have to be damaged to a large extent than situated closely to core.

Moreover as a hypothesis we suppose that at some stages of irradiation damaged metal have to be partially restored by irradiation i.e. neutron bombardment. Nascent during irradiation structure undergo occurring once or periodically transformation in a direction both degradation and recovery of the initial properties. According to our hypothesis at some stage(s) of metal structure degradation neutron bombardment became recovering factor. Self-recovering section of RPV steel radiation embrittlement kinetics as indication of material intelligent behavior. As a result oscillation arise that in turn lead to enhanced data scatter. In this case we have to consider irradiation as a recovery factor.

For the sake of correctness it is necessary to remember that there is an example when contrary to the famous radiation embrittlement in metals neutron irradiation at some range of fast neutron doses is in position to improve both the strength and ductility of steel.

Foregoing hypothetical assumptions on "low-dose effects" in terms "radiation embrittlement contains oscillatory component" and "radiation annealing of the radiation embrittlement" is questionable and needs additional experimental verification and profound scientific study.

Abstracts

SHM 1

Location: Lecture Theatre 3, Diamond Building

Session Chair: C. Sbarufatti

Monday 11th July

Recent Advances on Pseudodynamic Hybrid Simulation of Masonry Structures

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ABSTRACT

Hybrid Simulation has been introduced to simulate the seismic response of civil structures. The hybrid model of the emulated system combines numerical and physical subdomains and its dynamic response to a realistic excitation is simulated using a numerical time-stepping response history analysis. In the current practice, lumped parameters structural topologies such as shear type frames or inverted pendulum characterize the physical subdomain and the design of the testing setup is straightforward. Although hybrid simulation has been extensively exploited for testing concrete and steel structures, in the authors' knowledge, there is still a paucity of scientific publications devoted to masonry applications. This is in contrast to the inherent uncertainty carried by masonry failure mechanisms, which hinders any attempt of implementing predictive numerical models. From this perspective, this paper summarizes our recent research achievements aimed at extending hybrid simulation to distributed parameter specimens, such as masonry walls, using the minimum number of actuators. The great potential of reduction bases in driving the substructuring process has been shown in a previous work and here is enhanced to floating physical subdomains.

Keywords: *hybrid simulation, substructuring, distributed parameter systems, masonry structure retrofitting.*

Model-based fatigue prognosis of fiber-reinforced laminates exhibiting concurrent damage mechanisms

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ABSTRACT

Prognostics of large composite structures is a topic of increasing interest in the field of structural health monitoring for aerospace, civil, and mechanical systems. Along with recent advancements in real-time structural health data acquisition and processing for damage detection and characterization, model-based stochastic methods for life prediction are showing promising results in the literature. Among various model-based approaches, particle-filtering algorithms are particularly capable in coping with uncertainties associated with the process. These include uncertainties about information on the damage extent and the inherent uncertainties of the damage propagation process. Some efforts have shown successful applications of particle filtering-based frameworks for predicting the matrix crack evolution and structural stiffness degradation caused by repetitive fatigue loads. Effects of other damage modes such as delamination, however, are not incorporated in these works. It is well established that delamination and matrix cracks not only co-exist in most laminate structures during the fatigue degradation process but also affect each other's progression. Furthermore, delamination significantly alters the stress-state in the laminates and accelerates the material degradation leading to catastrophic failure. Therefore, the work presented herein proposes a particle filtering-based framework for predicting a structure's remaining useful life with consideration of multiple co-existing damage-mechanisms. The framework uses an energy-based model from the composite modeling literature. The multiple damage-mode model has been shown to suitably estimate the energy release rate of cross-ply laminates as affected by matrix cracks and delamination modes. The model is also able to estimate the reduction in stiffness of the damaged laminate. This information is then used in the algorithms for life prediction capabilities. First, a brief summary of the energy-based damage model is provided. Then, the paper describes how the model is embedded within the prognostic framework and how the prognostics performance is assessed using observations from run-to-failure experiments.

Keywords: *CFRP; matrix cracks; delamination; fatigue damage prognosis; particle filtering; sequential Monte Carlo*

On Correlation and Causality in Structural Dynamics

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ABSTRACT

There has long been interest in the concept of causality in systems theory and structural dynamics. In the context of nonlinear system identification, the Hilbert transform method of detecting nonlinear behaviour depends crucially on the concept of causality. One might argue that there are actually two interrelated definitions of causality current and important in structural dynamics, and more widely in general time series analysis. The first definition of causality, one might call the responsibility definition, is based on the idea that an event B (the effect) only occurs if an event A (the cause) occurs. The second definition – the priority – definition, asserts that cause must precede effect (in time) in any classical dynamic situation. The responsibility concept of causality is already embedded in structural dynamics, as it largely maps onto the idea of correlation; the coherence function associated with an FRF is essentially a representation of the idea. The priority concept is the crucial ingredient in the Hilbert transform test mentioned earlier. The objective of the current paper is to discuss where causality can illuminate processes in both linear and nonlinear structural dynamics and to provide illustrations based on transmissibilities and FRFs for MDOF systems. The second thread of the paper draws on the fact that concepts from the field of econometrics have recently shown promise in their application to structural dynamics. One such concept – Granger causality - is highlighted, and its applications on linear and nonlinear dynamic systems are discussed in the context of the illustrations discussed earlier.

Damage Identification Research of Spatial Structure Using Wavelet Packet Energy Method Based on Dynamic Strain

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ABSTRACT

As public buildings, the safety of spatial structures needs more attention. Due to the features of huge in size, a large number of components, complex force conditions, and environmental factors, it is more difficult to identify damage and monitor health status for the spatial structures. And it is inappropriate to identify the local damages using overall damage index or model updating of the whole structure. It needs sensitive indexes to identify the local damage directly with the environmental factors under consideration.

Dynamic strain response could reflect the local of change of the structure which is also a kind of signal easily obtained. And the progress of modern testing technology also guarantees the reliability of the strain test results. Taking into account the characteristics of large space structures, this paper proposed a way to identify the member's damages using wavelet packet energy method based on dynamic strain response. This approach combines both the advantages of the wavelet packet decomposition and dynamic strain, and could apply environmental excitation or local pulse excitation which is more suitable for field test of large space structures.

Firstly, the finite element model of the typical grid structure was established. And then excitations and damage cases were simulated, including environmental excitation or local pulse excitation. Then dynamic strain response of the structure was obtained for wavelet packet decomposition. The comparative results showed that index based on wavelet packet strain energy is a good indication of local damage including both tiny damage or near failure damage. And the excitation position could be chosen freely within the range of signal attenuation.

The feasibility of the approach was conducted to a practical spatial structure, Guangzhou Opera House. The large space steel structure is a novel and complex structure in Guangzhou, China which is composed of a series of irregular space flap. Additional mass were added to simulation damage cases which cause the change of members stress. And the strain response signals of the members were obtained by optical fiber strain sensors under environmental excitation. Before and after the additional mass were added, the wavelet packet energy of the strain response changed significantly. And the change could clearly indicate the location of the members which were added mass. The results showed that the proposed method could identify the changes of the local performance of large space structures member.

Keywords: spatial structure，Damage identification，Dynamic strain，Wavelet Packet Decomposition

Special Session: Smart Materials

Location: Lecture Theatre 4, Diamond Building

Session Chair: O. Ganilova

Monday 11th July

Vibration Response and Damping Behaviour in Sandwich Composites with Magnetorheological Elastomer Core

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ABSTRACT

A multi-scale asymptotic expansion method is developed to analyse the transverse vibrations and damping behaviour of sandwich composite plates with magnetorheological (MR) elastomer core and unidirectional composite ply face-sheets. The core provides a constrained layer damping (CLD) to the plate. In this method, the dynamic response of the sandwich plate is modelled by exact 3-D equations using the complex modulus representation for the viscoelastic core. The governing equations are first expressed in terms of non-dimensionalized field quantities and length scales and then suitably rearranged to relate the through-thickness derivatives of the field variables to the in-plane quantities. Substitution of the asymptotic expansions of the field variables in terms of the plate thickness parameter in the non-dimensionalized equations and equating the like powers of the parameter gives recursive sets of relations of different orders. These relations are integrated through the plate thickness to give governing differential equations for various orders. The lowest order equation corresponds to the classical plate theory while the higher order corrections include effects of rotary inertia and shear deformation. The use of multiple time scales eliminates secular terms and ensures valid bounded solutions. The complex eigen values for the free vibration problem give both the plate natural frequencies and the modal loss factors. The analytical results are compared with numerical solutions. The influence of the changing viscoelastic properties under the influence of a varying magnetic field and the plate geometric parameters on the dynamic response is examined through a parametric study.

Keywords: *Sandwich Composite, Vibrations, Magnetorheological core, Multiscale Asymptotic Expansion*

Semi-active Vibration Control Using Piezoelectric PZT Composite Films

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ABSTRACT

This interdisciplinary research work of civil and electrical engineers deals with the piezoelectric ceramic material, lead zirconate titanate (PZT) and its potential future use as a semi-active structural control device in a civil engineering context. The study examines first what is currently known about piezo ceramics and their existing applications in fields such as energy harvesting and as sensors. The main part of the paper deals with implementing piezoelectric ceramics as a semi-active damping system for the vibration control of lightweight non-structural components. This procedure is experimentally analysed for the damping response of an oscillating aluminium cantilever beam. The study shows that, by using an RLC equivalent circuit in conjunction with a piezoelectric ceramic transducer, the vibrations in the beam due to an initial disturbance is significantly reduced. By correctly optimizing the components within the circuit, the resonance frequency of the circuit can be tuned to the natural frequency of the beam. The experiments show that an optimal choice of circuit parameters may increase the damping performance up to 180 %.

Keywords: *Semi-active, smart materials, piezoelectric, piezo ceramic, PZT*

Optimal Tuning Of Shunt Parameters For Lateral Beam Vibration Attenuation With Three Collocated Piezoelectric Stack Transducers

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ABSTRACT

Structural vibration may occur in mechanical systems leading to fatigue, reduced durability or undesirable noise. In this context, shunting piezoelectric transducers to RL-shunts can be an appropriate measure for attenuating lateral beam vibrations. The achieved vibration attenuation significantly depends on an adequate tuning of the shunt to the structural resonance mode. In this paper, an existing method for resonant shunt circuit tuning based on electrical impedances is extended for lateral vibration attenuation of the first mechanical mode of a beam with circular cross-section and three collocated resonantly shunted stack transducers. It is shown by numerical simulation that a presented electrical impedance model including only the first beam mode can be used for the shunt parameter optimization if higher beam modes are taken into account.

Keywords: *piezoelectric shunt damping, integrated piezoelectric transducers, electromechanical impedance, numerical optimization*

Fuzzy Control of Three-Degree-of-Freedom Systems using Multiple MR Dampers

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ABSTRACT

Smart structural control is now emerging as an alternative to conventional earthquake resistant design and traditional structural control techniques. Fuzzy control is one of the promising control strategies that could be used for this function. Magnetorheological (MR) dampers are considered one of the promising semi-active control devices that can be used to control the structural response of buildings under earthquake excitation. The properties of MR dampers can be controlled using several control techniques such as Fuzzy Logic.

In this paper, a fuzzy control scheme is proposed to control the response of a three degree of freedom system under earthquake excitation. The system is equipped with three MR dampers with one for each degree of freedom, i.e., floor. The system comprises an optimization component which identifies the most optimum firing sequence of the MR dampers in order to achieve the best controlled response. It is envisaged that not all three MR dampers are fired simultaneously; only selected ones are fired as per the decision of the optimization scheme. A comparative analysis is, finally, conducted in order to demonstrate the validity of the proposed scheme.

Keywords: *Smart Structures, Structural Control, MR Dampers, Fuzzy Control, Structural Dynamics.*

Energy Harvesting based on the Hybridisation of two Smart Materials

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ABSTRACT

Recently, there has been an increased demand for power harvesting as a source of providing renewable energy. One of the most promising technologies due to their high power densities are piezoelectric devices, harvesting vibrational energy. There has been extensive research done in the area of energy harvesting using smart materials. However, the majority of this work is dedicated to the application of one type of smart material, such as piezoelectric or shape memory alloy. The aim of this paper is to develop a completely novel concept of a hybrid device combining piezoelectric and shape-memory alloy effects. The resulting device has a strong potential for miniaturisation and practical biomedical applications in environments characterised by thermal fluctuations. Both finite element and analytical models were developed to describe the dynamic behaviour of this innovative device. Both models predicted parametric behaviour for an input frequency of 988 Hz. Performance of the device was comparable to existing energy harvesting devices. The limitations and benefits of each modelling approach are also discussed.

Abstracts

Earthquake 1

Location: Lecture Theatre 4, Diamond Building

Session Chair: C. Lord

Monday 11th July

Seismic response of high-strength steel moment connections used in special moment frames

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ABSTRACT

This study elucidates experimentally the cyclic behaviour of two moment connection subassemblages using high-strength steel. Due to the high yield ratio of the high-strength steel, the moment connections were designed to characterize widened beam flanges at the column-to-beam interface. The test results indicated that specimens formed a plastic hinge in the beam section away from the column face. Extensive yielding and plastification were observed in the beam section at the intended plastic hinge location. Local buckling of the beam flange and web occurred finally and caused the strength deterioration. Both specimens achieved an interstory drift angle of 5% rad and the plastic rotation of more than 3% rad. Using the high-strength steel, specimens with widened beam flange moment connection can develop satisfactory strength and ductile behaviour.

Keywords: *High-strength steel; moment connection; plastic hinge.*

Control of structures subjected to earthquake excitation based on non resonance theory

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ABSTRACT

One case of the earthquake analysis is the response spectrum analysis. Where the structure is designed to protected by earthquakes which represented from design spectrum. However, very often the real earthquake that applied to structure exceeds the design spectrum. In that case the ductility of structure and the demand capacity are the line of defence to face that situation. As a results damage will occurred in structure and the cost of rehabilitation is unavoidable. An alternative direction which proposed in this paper is to design structure, equipped by control devices, capable to resist the incoming earthquake and remaining in elastic range and thus without damage. The idea is that once the response spectrum of the incoming earthquake is higher than the design spectrum at the eig- periods of the structure the control devices will be activated, in order of milliseconds, and will change the period of structure. In that case the structure will avoid the “resonance” with the incoming earthquake and its response spectrum will lie lower that the design spectrum at the new eig-periods of the structure. From the numerical results it is shown that the above control strategy is efficient in reducing the response of building structures, with small amount of required control power.

Keywords: *Response spectrum, design spectrum, structural control, earthquake engineering.*

A Practical Design Method for Seismic Strengthening of RC Frames Using Friction-Based Passive Energy Dissipation Devices

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ABSTRACT

In this paper, a practical design solution for more efficient design of friction-based passive control systems is suggested, by considering the selected design earthquakes. In general, the effectiveness of the friction-based supplemental dampers is limited to a narrow range of slip loads. In addition, height-wise slip load distribution pattern can notably affect the overall seismic performance of the structures controlled with friction devices. In this study, the efficiencies of five different height-wise slip load distribution patterns for friction-based passive dampers are first compared; and accordingly, a practical solution for slip load distribution is proposed. The studied system consists of a non-structural concrete panel with a friction connection at the top and three more peripheral supports to provide appropriate boundary condition for the concrete wall panel. To assess the effectiveness of the supplemental friction wall system, extensive nonlinear dynamic analyses have been conducted on 3, 5, 10, 15, and 20-storey RC frames subjected to seven real and synthetic spectrum compatible earthquakes. Subsequently, an empirical equation is suggested to design RC frames with friction wall dampers. The preliminary results show that using the proposed equation can significantly improve the seismic performance of the controlled structures.

Keywords: *Passive damper; Structural optimization; Non-linear analysis; Seismic performance*

Dynamic Behaviour of a Seven-Storey Seismically Isolated Building during the 2011 Tohoku Earthquake

Toshihide Kashima

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ABSTRACT

The Building Research Institute (BRI) operates a strong motion network that covers buildings in major cities across Japan. In 2010, as one of stations in the BRI strong motion network, the seven-story Tsukuba Town Hall building, which is a precast prestressed concrete frame structure, was equipped with a seismic isolation system consisting of; 11 natural rubber bearings, 45 lead-plugged rubber bearings and 9 steel-damper-combined rubber bearings.
The building suffered extremely strong shaking with the Tohoku Earthquake of 11 March 2011. The accelerometer installed on the ground near the building, 334 kilometres far away from the epicentre, red out the peak ground acceleration higher than 1G. Even in this situation, the seismic isolation system successfully reduced the seismic acceleration exceeding 3 m/s2 on the foundation to less than one third. The analysis of the strong motion data obtained during the 2011 Tohoku Earthquake verified the excellent performance of the seismic isolation system. The maximum deformation of the isolation devices reached nearly 70 mm. Based on the analysis of the strong motion data on 84 earthquakes that occurred during the period from 2010 to 2016, dynamic characteristics of the seismic isolation system and the superstructure were discussed. The stiffness of the seismic isolation system showed a clear decline in the large displacement range. The damping effect of the seismic isolation system remained satisfactorily stable.
We concluded that the seismic isolation system installed in the Tsukuba Town Hall building worked properly and effectively as expected in the structural design.

Keywords: *Seismic Isolation System, Strong Motion Data, 2011 Tohoku Earthquake*

Development of Adaptive Rubber Bearings

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ABSTRACT

A new seismic isolator made of rubber material is proposed in this study. This seismic isolator is called the adaptive rubber bearing (ARB) because of its adaptive characteristic. The lead material which is usually found in lead rubber bearing (LRB) results in heavy environmental burden and lower yield strength and damping due to rising temperature during earthquakes, causing larger displacements than we would expect. The designed mechanisms in the proposed seismic isolator make this device relatively easily manufactured and also provide extremely high damping to the bearing, which is highly desired by engineers in practice. The proposed rubber bearing that uses lead-free materials is completely passive device yet possesses adaptive stiffness and adaptive high damping. The change in stiffness and damping is predictable and can be calculated at specifiable and controllable displacement amplitudes. The major advantage of the adaptive characteristic of a seismic isolator is that a given system can be optimized separately for multiple performance objects at multiple levels of earthquakes. In this paper, theoretical formulations have been derived to explain the mechanical mechanisms of the proposed device. Experimental results are also provided to validate the advanced concept of the proposed isolator.

Keywords: *Seismic isolation systems; High damping; Adaptive device; Passive control; Earthquake engineering; Earthquake proof systems*

Tuned Mass Dampers

Location: Lecture Theatre 4, Diamond Building

Session Chair: I. Lazar

Monday 11th July

Optimal Design And Practical Implementation Of Eddy-Current Tuned Mass Dampers with Permanent Magnets For Multi-Storey Buildings

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ABSTRACT

This work proposes an implementation example of two tuned mass dampers (TDM) on a reduced scale two storey building. The TMD, in which the damping is magnetically adjusted without contact, is a laboratory prototype built in CARTIF (Spain). This TMD consists on a one degree of freedom system formed by a permanent magnet (mass) fixed to a flexible link (elasticity) and an aluminium plate at an adjustable distance to the magnet (damping). The tuning of the TMDs is carried out by considering the passive system as a feedback controller. The system identification and the experimental results show the validity of theoretical approximations and the design criterions.

Keywords: *Structural control, Passive vibration control, Tuned mass damper, Optimization.*

Application and Testing of Hybrid Mass Dampers for Vibration Control of Canton Tower

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ABSTRACT

In this work, the use of a newly proposed HMD is investigated to protect Canton Tower against undesirable vibration levels and improve its serviceability under wind loading, which is composed of a TMD with two-stage damping level, and a small AMD driven by linear induction motors and mounted on the TMD. For convenient analysis, the tower is simplified as 51 connected rigid panel series model. A reduced-order model of the simplified system is developed using an improved eigenmode reduction method. An H2/LQG control algorithm and a fuzzy logic control are employed for active controller design. The performance of the proposed HMD system is investigated and compared with those of corresponding TMD and ATMD systems. Experimental verification studies are also conducted to test the performance of the proposed HMD system. Finally, the performance of Canton Tower was tested under both cases of free vibration and Typhoon. Results show that the proposed HMD system is feasible, effective and economical.

Keywords: *Vibration Control, HMD system, H2/LQG, fuzzy logic controller, ATMD systems*

Simulation of the response of a lively footbridge under pedestrian loading with two tuned mass dampers for its two first modes (2.1Hz and 2.5Hz)

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ABSTRACT

Structures subjected to excitations like human induced vibrations may produce large accelerations and serviceability limit state problems. Passive, semi-active and active vibration controls have been proposed as possible solutions to reduce the vibration level at civil structures such as bridges, multi-storey buildings or slender floor structures, among others [1]. It is known that Tuned Mass Dampers (TMD) mitigates the vibration response of a structure by increasing its damping through the application of inertial forces generated in response to the movement of the structure [2]. Recently, different TMD implementations have been proposed in order to improve the tuning of mechanical parameters. In the case of structures with spatially distributed and closely spaced natural frequencies, the TMD design may not be obvious because Den Hartog's theory [3] may not be applied due to the existence of a coupling between the motions of the vibration modes of the structures and the used TMD's [4]. Alternative design techniques are applied for the case under study consisting on an arched bridge with a main span 40m long and several shorter access spans. The first two first modes are at 2.1Hz and 2.5Hz, both in the range prone to be excited by walking. Also the third one (at 3.18Hz) could be excited by runners.

For the simulation, firstly, a finite element model of the bridge is created in a commercial CAE software and static and modal response is numerically estimated. Then, experimental measurements using static loading test and ambient vibration tests are performed. Initial finite element model is adjusted to match with the static response by fitting some selected parameters. Modal parameters (natural frequencies, mode shapes and modal damping) are extracted and after that the current finite element model is updated. Once the numerical model is calibrated, TMDs are attached. The problem of finding the optimal location and tuning is not a simple one. For understanding the coupled response, several simulations are carried out, from the logical one (TMD located just in the middle of the main span and tuned at 2.1Hz) to others. The responses of the footbridge for different scenarios (depending on the number of TMDs installed and their position) are compared in order to extract some interesting conclusions.

Keywords: *Structural control, Passive vibration control, tuned mass damper, optimal control.*

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FEASIBLITY OF VISCOUS MASS DAMPER WITH BINGHAM FLUID ORIGINED FORCE RESTRICTION MECHANISM FOR BASE-ISOLATED STRUCTURE

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Viscous mass dampers are considered as the effective devices for seismic control recently. For the seismic control of base isolation structure, it is necessary to reduce not only the deformation of the isolation layer but also the floor response acceleration of the superstructure. From a series of analytical studies of viscous mass dampers, it was shown that viscous dampers with force restriction mechanism by the friction can reduce the displacement of the base isolation layer. But at the same time it was shown that they cannot reduce the floor response acceleration of the superstructure depending on the input ground motions. To improve them, viscous mass dampers with bingham fluid origin force restriction (Bingham fluid – viscous mass damper, hereinafter called BF-VMD) is suggested.

The BF-VMD has four design variables to decide, the amount of the apparent mass, the viscous damping coefficient, the stiffness of shock absorbed spring, and the damping coefficient of the bingham fluid. In this paper, base isolated five-story reinforced concrete structure incorporated with BF-VMD or ordinary oil dampers with relief mechanism (hereinafter called OD) at the base isolation layer are considered. Three kinds of design criteria that are the displacement of the base isolation layer, the floor response acceleration, and the coefficient of the shear force, are defined for three levels of input ground motions, and the design variables that can fulfill all the design criteria are chosen by the optimum design method.

The maximum responses that are given by the optimum design results shows that structure with optimized BF-VMD can satisfy all the design criteria defined above, whereas the structure with OD cannot satisfy the design criteria of the floor response acceleration. To know the redundancy of the maximum response by optimized BF-VMD, sensitivity analysis for BF-VMD is conducted. The results show that the damping coefficient of the bingham fluid and the stiffness of the shock absorbed spring has some redundancy on the maximum responses. The parametric study on the number of OD shows that OD cannot satisfy the design criteria for any cases. It means that only BF-VMD can satisfy the design criteria defined in this study.

For the conclusion BF-VMD has better performance for the isolation effect compared to the conventional oil dampers.

Abstracts

Special Session: Civil SHM

Location: Lecture Theatre 3, Diamond Building

Session Chair: J. Brownjohn

Tuesday 12th July

Advanced Methodologies and Techniques for Monuments Preservation: the Trajan Arch in Benevento as a Case of Study

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ABSTRACT

An effective assessment of the static and dynamic structural behavior of historical monuments requires the development and validation of suitable adaptive structural models using high quality experimental data acquired with an effective continuous and distributed monitoring. Furthermore, this adaptive strategy allows an effective evaluation of the health status and of the evolution along the time of a historical monument, providing relevant information to plan appropriate actions for its long-term preservation.

The Trajan Arch in Benevento was chosen as a case of study to develop and apply this new adaptive strategy in cultural heritage preservation. The paper, after a description of the innovative monitoring system, based on state-of-the art mechanical sensors, presents and discusses the results of two tests, comparing the measurements with the predictions of an adaptive structural FEM model developed for the dynamical simulation of the Trajan Arch.

Keywords: *monument preservation; monolithic folded pendulum; distributed monitoring system; structural dynamic analysis.*

HIL model and cable stayed footbridge monitoring/control

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ABSTRACT

Elaborations from an experimental campaign on a footbridge are re-elaborated. After the parameters of a consistent numerical model have been calibrated, recorded signals and numerical analyses are exploited in view of improving the structural monitoring features adopted up to now. The transient character of human crossing is demanded to a further suitable numerical model. As an ultimate target of the investigation, the potential of simple structural control schemes on the cable tension is discussed.

Keywords: *Cable, Cable-stayed bridge, Human induced loading, Structural monitoring, Structural control*

Improving Emergency Response Using Wearable Wireless Sensor Networks and Structural Health Monitoring Systems

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ABSTRACT

Structural collapse and damage which have been occurred during past decades have caused severe failures especially in strategic infrastructures and public buildings. Considering the density of people in buildings, especially in crowded ones, a natural disaster may cause a large number of injuries and deaths. Considering the resiliency concept, it is needed to decrease the failure and its consequences especially in case of lost lives. Since saving life is a time dependent procedure, the faster rescue teams search for victims, the more injured people will survive. This paper presents a novel practical method to improve the emergency response of rescuers after the disaster occurrence using SHM and WSN. The proposed system includes fixed SHM nodes which measure structural related parameters like vibration, humidity, and etc. It also includes mobile nodes which are wearable wristbands worn by people and collect data including approximate location of victims and health status. This system provides the rescue teams with data related to the damaged parts of the buildings, number of people who have been trapped inside the building, their location by means of indoor localization, and their vital status. These data which will be collected and analyzed in real-time, are being used for building damage level assessment and also help rescuers to locate victims faster and save more lives. These fixed and mobile nodes construct a wireless sensor network which stays functional even during power outage by means of rechargeable batteries. Through this system, it is possible to assess the structural health and also improve the emergency response when a disaster happens. The progress in the emergency response will improve the searching and rescuing process. It will also help rescuers to optimize their time and increases the performance significantly.

Keywords: *Structural Health Monitoring, Emergency response, Resilience, WSN, Smart Sensors*

A new approach to identification of cracks in beams and experimental verification

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ABSTRACT

Cracking is a common type of damage in structural beams. Existing methods for the detection of cracks in beams are most commonly based on representing a crack by a reduction of the bending stiffness over a certain segment. While such representation may be acceptable for slender beams, it can be problematic for relatively thick beams which are typical in civil engineering structures. In the present study an explicit cracked beam element model is adopted, in which the effect of the crack is comprehensively described by a cracked stiffness matrix relating to the crack location and the crack depth. The cracked beam element model is implemented in a finite element model updating framework for the identification of the crack parameters. This paper provides an overview of this new crack identification approach and the verification of the effectiveness of the method from laboratory experiments. In the experimental verification, cracked beam specimens have been tested to extract the modal frequency and mode shape data, and these are compared with the predictions using the cracked beam element model. The measured modal data are also employed to carry out (inverse) crack identification to further verify the effectiveness of using the cracked beam element model for crack damage identification.

Keywords: *Thick beam; Cracked beam element; Damage identification; Finite element model updating; Aluminium beams*

Viability of optical tracking systems for monitoring deformations of a long span bridge

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ABSTRACT

Characterisation of both dynamic and quasi-static deformations of suspension bridges is essential to manage their serviceability and to appreciate the internal forces due to the various live loads effects of wind, temperature and traffic. GPS is commonly used for the largest, most flexible structures but the limitations are not well understood and accelerometers cannot capture the extreme low frequency movements. Optical displacement tracking has potential to avoid all these errors but has different types of limitation that need to be evaluated and mitigated. In attempt to cross-validate optical tracking technology against GPS data, a commercial optical system the Imetrum 'Video Gauge' was used at Humber Bridge, after first initial experiments on a short span bridge to identify the most effective way to deploy it in the field for measurements at very long range. Some results are presented illustrating the character of the observed deformations and the limitations of the various forms of deformation monitoring instrumentation. In particular limitations of GPS were highlighted through comparison with Video Gauge and accelerometer data.

Keywords: *bridge monitoring GPS acceleration optical*

SHM 2

Location: Lecture Theatre 3, Diamond Building

Session Chair: N. Dervilis

Tuesday 12th July

Sensor Selection Based On Principal Component Analysis For Fault Detection In Wind Turbines

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ABSTRACT

Growing interest for improving the reliability of safety-critical structures, such as wind turbines, has led to the advancement of structural health monitoring (SHM). Existing techniques for fault detection can be broadly classified into two major categories: model-based methods and signal processing-based methods. This work focuses in the signal-processing-based fault detection by using principal component analysis (PCA) as a way to condense and extract information from the collected signals. In particular, the goal of this work is to select a reduced number of sensors to be used. From a practical point of view, a reduced number of sensors installed in the structure leads to a reduced cost of installation and maintenance. Besides, from a computational point of view, less sensors implies lower computing time, thus the detection time is shortened.

The overall strategy is to firstly create a PCA model measuring a healthy wind turbine. Secondly, with the model, and for each fault scenario and each possible subset of sensors, it measures the Euclidean distance between the arithmetic mean of the projections into the PCA model that come from the healthy wind turbine and the mean of the projections that come from the faulty one. Finally, it finds the subset of sensors that separate the most the data coming from the healthy wind turbine and the data coming from the faulty one.

Numerical simulations using a sophisticated wind turbine model (a modern 5MW turbine implemented in the FAST software) show the performance of the proposed method under actuators (pitch and torque) and sensors (pitch angle measurement) faults of different type: fixed value, gain factor, offset and changed dynamics.

Keywords: *fault detection; sensor selection; principal component analysis; wind turbines; FAST*

Quantification Of Uncertainty For Experimentally Obtained Modal Parameters In The Creation Of A Robust Damage Model

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ABSTRACT

Computational modelling is an important method in generating predictive models of engineering systems. These computational models are generally deterministic and therefore often ignore the inherent uncertainty in experimental results. Where the model predictions are to be used for dam- age identification this lack of uncertainty can lead to less robust classification, as damage states can appear more clearly separated than may be true for experimental data. The approach used in generating damaged state model predictions must therefore identify and quantify the main sources of uncertainties. By quantifying the main sources of uncertainties, a Naive Bayes approach can be used to define decision boundaries that incorporate this uncertainty, improving damage predictions. The combination of the computational model and a Naive Bayes approach will lead to a more detailed and realistic representation of the actual system. In this paper quantification of the uncertainties from modal tests for a prismatic metallic cantilever beam, with different levels of damage, is presented. The main sources of uncertainty are categorised and quantified before being applied to computational models using a Naive Bayes approach. The probability of the likelihood of damage classification is then shown for the inclusion of uncertainty in the damage model, showing the improvement in decision bound and therefore the improvement in the damage model.

Keywords: *Damage Modelling, Structural Health Monitoring, Uncertainty Quantification*

Design criteria for structural monitoring system: a preliminary approach

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ABSTRACT

Sensor technological enhancement and Information and Communication Technologies (ICT) meet together nowadays in the concept of Smart Cities, i.e. cities that offer an additional value to their inhabitants and visitors, such as monitored safety of infrastructures. Structural Health Monitoring (SHM) appeared as a tool for structural diagnosis of buildings or civil engineering facilities, for both static and dynamic behaviours. Early applications required difficult and costly experimental setups. However, new sensor typologies, such fibre optics or MEMS, and wireless communications offer today a whole new scenario of possibilities, such as the permanent seismic monitoring of historical heritage. Nonetheless, the design of a SHM system often comprises a numerical model representative of the monitored structure, and useful for a better selection of the characteristics and location of each sensor. This approach is usually slow and costly, hence simplified criteria are proposed here to make a rapid preliminary design of a dynamic SHM system based on the evaluation of dynamic parameters (e.g. modal participation factors or natural frequencies). The design methodology is illustrated through its use in the development of a distributed network of monitored structures at L'Aquila.

Keywords: *structural monitoring, design criteria, structural dynamics, cultural heritage, smart city.*

Tool wear state clustering in milling based on recorded acoustic emission

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ABSTRACT

It is widely accepted that tool wear has a direct impact on a machining process, playing a key part in surface integrity, part quality, and, therefore, process efficiency. By establishing the state of a tool during a machining process, it is possible to estimate both the surface properties and the optimal process parameters, while allowing intelligent predictions about the future state of the process to be made. Thus ultimately reducing unexpected component damage. This state estimate can be achieved by implementing a variety of in-process monitoring techniques and observing the development of selected data features as the wear state of the tool progresses. This paper explores the use of a principal component analysis (PCA) along with a multi-class support vector machine (SVM) to cluster a set of tools' wear states, based upon sampled acoustic emissions (AE) released during ball-nosed milling of Titanium-5Al- 5Mo-5V-3Cr (Ti-5553).

Features of Nonlinear Vibration-Based Structural Health Monitoring

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Abstract:

For the last two decade, there has been a growing interest to use the vibration-based Structural Health Monitoring (SHM) as a global assessment method for existing infrastructures. This technique provides a tool for assessing inaccessible structure areas. The vibration-based technique includes different approaches which can be classified as linear or nonlinear. The former one is faced by various obstacles preventing it from going beyond research topics in civil engineering fields. Accompanied with the linear, the nonlinear method overcomes some of these disadvantages, for which the existence of a datum for the intact structure is a necessity. This datum is usually not available for existing infrastructure as mostly all the codes do not enforce collecting the structure dynamic response just after construction as a datum for future monitoring. However, the need of a reference can be eliminated in the nonlinear approach by detecting special features occurring only due to the nonlinear structure behaviour in the presence of damages. The aim of this paper is to highlight some of these features such as sub-harmonic and supper-harmonic components, which could be used as indicators for existence of degradation. Firstly, an analytical investigation is carried out in which a concrete post with breathing crack is modelled using MATLAB. Secondly, the system stiffness is determined based on the breathing crack situation either it is opened, partially opened, or fully closed. Then the system dynamic response is determined for different level of deterioration illustrating the corresponding nonlinear features.

Keyword: sub-harmonic, supper-harmonic, Nonlinear Vibration, breathing crack.

Abstracts

Special Session: Hybrid Testing

Location: Lecture Theatre 3, Diamond Building

Session Chair: O Bursi & N Tondini

Tuesday 12th July

Hybrid simulation applied to fire testing: a newly conceived partitioned static solver

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ABSTRACT

The paper presents development and application of a thermomechanical static solver based on the Finite Element Interconnecting Method (FETI) to be employed in hybrid fire tests. Hybrid fire test produces a time-history response of a hybrid model that comprises numerical and physical substructures to combined mechanical and thermal excitation. Hybrid fire test is advantageous to whole building full-scale fire tests because it allows testing of structural elements that exhibit a highly nonlinear fire behaviour in relatively small furnaces under realistic boundary conditions derived from a numerically model of the remainder of the structure. On these premises, the paper comprehensively describes the proposed static solver by highlighting its ability to guarantee compatibility and equilibrium at the interface between the physical substructure (PS) and the numerical substructure (NS), both for non-floating and floating subdomains as well as for nonlinear behaviour of the PS. The development of the solver has been driven by laboratory practice: an error propagation analysis that takes into account errors and uncertainties, such delay and measurement noise, is incorporated. The validation carried out in a fully numerical framework, i.e. the PS is also numerically modelled, shows promising outcomes for future experimental implementations.

Keywords: *Hybrid fire testing, FETI algorithm, error propagation analysis, experimental procedure*

A comparison of online and offline experimental substructuring methods for the simulation of complex linear dynamic systems

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ABSTRACT

Online hybrid (numerical/physical) dynamic substructuring simulations (HDS) on an as-built/isolated viaduct and on a petrochemical piping subject to non-stationary seismic loading have shown their potential for efficient realistic dynamic analysis of almost any type of structural system. Moreover, owing to ever faster and more accurate testing equipment, dynamic substructure coupling developed in mechanical engineering through a number of different offline experimental substructuring methods operating both in time, e.g. the impulse-based substructuring (IBS), and frequency domains. Numerous studies have dealt with the above-mentioned methods and with associated error/uncertainty propagations issues. Nonetheless, there is still a paucity of publications devoted to: i) the comparison of the performances of these methods from an error/uncertainty perspective; ii) the possibility of their exploitation in a complementary way to both improve and speed up the overall experiment/simulation. In this paper, we compare the performances of these methods including standard time integration schemes and the coupling algorithm of subdomains based on an advanced parallel finite element tearing interconnecting algorithm. Moreover, we include typical random uncertainties coming from devices and operators exploited in the analysed methods. Main results and comparisons based on Monte Carlo sampling of three- and five-DoF linear systems point out that the HDS method exhibits better performances with respect to phase and energy errors whilst the IBS slightly prevails on coefficients of variation of coupling node displacements.

Keywords: *Uncertainty propagation, online/offline substructuring method, offline methods, hybrid dynamic simulation.*

A Novel Methodology for Hybrid Fire Testing

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ABSTRACT

This paper describes a novel methodology for conducting stable hybrid fire testing (HTF). During hybrid fire testing, only a part of the structure is tested in a furnace while the reminded structure is calculated separately, here by means of a predetermined matrix. Equilibrium and compatibility at the interface between the tested “physical substructure” and the “numerical substructure” is maintained throughout the test using a dedicated algorithm. The procedures developed so far are sensitive to the stiffness ratio between the physical and the numerical substructure and therefore they can be applied only in some cases. In fire field, the stiffness of the heated physical substructure may change dramatically and the resulting change in stiffness ratio can lead to instability during the test. To overcome this drawback, a methodology independent of the stiffness ratio has been developed, inspired from the Finite Element Tearing and Interconnecting (FETI) method, which has been originally developed for substructuring in numerical analyses. The novel methodology has been successfully applied to a hybrid fire test in a purely numerical environment, i.e. the physical substructure was also modelled numerically. It is shown that stability does not depend on the stiffness ratio and that equilibrium and compatibility can be consistently maintained at the interface during the fire. Finally, the ongoing experimental program aimed at employing and experimentally validating this methodology is described.

Keywords: *Fire Testing, Hybrid Methodology, Physical substructure, Numerical Substructure*

A Pseudodynamic Testing Algorithm for Obtaining Seismic Responses of Structures

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ABSTRACT

A novel family method is proposed for the pseudodynamic tests. It can integrate favourable numerical properties together, such as the unconditional stability, explicit formulation, second-order accuracy and favourable numerical dissipation. Since this family method can have an explicit formulation of each time step its pseudodynamic implementation involves no iteration procedure. Consequently, the pseudodynamic tests can be easily conducted when compared to an implicit pseudodynamic method, where an iteration procedure must be involved for each time step. On the other hand, the properties of unconditional stability, second order accuracy and numerical dissipation indicate that the proposed pseudodynamic algorithm is very promising for solving inertial problems, where the total response is dominated by low frequency modes only and the high frequency responses are of no interest. The unconditional stability implies that there is no limitation on step size for the high frequency modes. Besides, the dominated low frequency modes can be reliably integrated by choosing an appropriate time step since the proposed family method can have a second order accuracy. Finally, the spurious participation of high frequency responses can be suppressed or filtered out by the desired numerical dissipation. The proposed pseudodynamic algorithm is very promising for a general pseudodynamic test or a substructure pseudodynamic test.

Keywords: *pseudodynamic test, numerical dissipation, structure-dependent method, unconditional stability*

Earthquake 2

Location: Lecture Theatre 4, Diamond Building

Session Chair: V. Gattulli

Tuesday 12th July

Networked Overlapping Control For Building Benchmark

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ABSTRACT

The article examines the problem of a wireless overlapped control design for seismically excited buildings. The earthquake-excited 20-story building benchmark study presents a new methodology based on overlapping decompositions, periodic digital network and switched linear systems approach. The solution consists of the construction of a wired overlapped LGQ controller which is followed by a wireless controller design. Simulation results illustrate the effectiveness of the proposed method.

Keywords: *Active structural control, networked control systems, overlapping decompositions*

Seismic test of building floor isolation using polynomial friction pendulum isolators

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ABSTRACT

Compared to structural base isolation, floor isolation is a more cost-effective and efficient means for seismic protection of vibration-sensitive equipment in a building structure. However, in order to protect the precision equipment, floor isolation usually has to satisfy more stringent isolation performance than that of base isolation; at the meantime, it also calls for less isolation displacement demand due to the indoor space limitation. In order to satisfy these multiple demands, in this study, a multi-functional floor isolation system (FIS) that consists of several variable-stiffness sliding isolators, called polynomial friction pendulum isolators (PFPIs), is proposed and studied. Due to its variable-stiffness nature, the proposed system is able to achieve the desired dual performance objectives that were selected during the design stage for two-level seismic loads. The variable-stiffness hysteretic property of the proposed system was verified by a shaking table test conducted on a prototype PFPI-FIS. Moreover, by using the parameters of the prototype system, the seismic performance of the prototype PFPI-FIS under ten ground motions, which represent earthquakes with different spectral contents and intensity levels, are investigated numerically. The simulated results demonstrate that the isolation performance of the PFPI-FIS does comply with the designated dual performance objectives, which yield either acceleration or displacement control depending on the earthquake intensity and isolator drift.

Keywords: *Floor isolation, multi-functional isolator, variable stiffness, pendulum isolator, polynomial function, performance design.*

Modelling the Response of Isolation Rubber Bearings with Variable Axial Loading

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ABSTRACT

Seismic base isolation systems protect thousands of structures and infrastructures all over the world. Its effectiveness for seismic protection is widely recognized owing acceleration reduction and minimization of the 'panic' effects for the occupants. This aspect has recently recognized of special interests also for strategic structures and facilities for which superior performances expected.
This work deals with the development of a modified model for simulating the horizontal response of rubber bearings, extending the existent procedures to variable axial loading. laboratory tests serve as the target for developing the numerical formulation.

Keywords: *seismic isolation, rubber bearing, biaxial loading, numerical modelling*

Experimental Study Of The Effectiveness Of Semi-Actively Implemented Power-Law Damping On Suppressing The Seismic Response Of A Base-Isolated Building

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ABSTRACT

This study focuses on verifying the effectiveness of the nonlinear power-law damping system on reduction of the vibration of base-isolated buildings with semi-actively implemented dampers over the ranges of resonance frequencies without causing detrimental effects over other frequency ranges. To verify the effectiveness of the proposed power-law damping system, shaking-table tests on a small-scale two-story physical building model are conducted. Random ground motions are used as the input excitations. The physical building model is equipped with a semi-active oil damper whose damping coefficient can be varied over four different values. This provides an effective mechanism for semi-actively implementing the power-law damping system. The shaking-table tests have demonstrated the effectiveness and robustness of the power-law damping and indicated that this can be a more practical solution to improving the performance of building base-isolation systems.

Keywords: *base-isolated building, semi-active oil damper, power-law damping, shaking- table test*

Application of Crescent-Shaped Brace passive resisting system in multi-storey frame structures

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ABSTRACT

The design of building structures that is capable of providing prescribed seismic performances is the fundamental objective of the Performance-Based Seismic Design (PBSD) approach. Matching a particular seismic response requires additional design freedom that the conventional structural elements (beam/column) fail to provide. Here, it is worth to highlight the role of innovative lateral resisting systems such as base isolation and dissipative systems, which can add flexibility to the design and help to achieve prefixed seismic performance objectives. Among different solutions, the seismic design of a two-storey reinforced concrete building equipped with a novel hysteretic device, namely Crescent-Shaped Brace (CSB), is presented. CSBs are characterised by a unique geometrical configuration, leading to an optimized nonlinear force-displacement behaviour that allows the structure to achieve prescribed multiple seismic performances. In this paper, we propose a procedure for the seismic design of the CSB devices within the framework of PBSD. The global behaviour of the devices is studied and verified for a multi-storey shear-type building structure by means of numerical analyses. The results obtained confirm the validity of the proposed design method and the effectiveness of the new hysteretic device. The force-displacement curve of the building matches the objectives curve (i.e. the one corresponding to the predefined performance objectives), thus ensuring the fulfilment of the prescribed multi-seismic performances.

Keywords: *Crescent Shaped Brace, Design method, Dynamic analysis, Performance Based Seismic Design.*

Earthquake 3

Location: Lecture Theatre 4, Diamond Building

Session Chair: A. Giaralis

Tuesday 12th July

Modelling the Axial Response of the Roll-N-Cage Device for Seismic Isolation

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ABSTRACT

The present study focuses on the axial characterization of the Roll-N-Cage isolation device. The procedure consists into two main steps: (i) laboratory investigations of a scaled prototype of the Roll-N-Cage system for evaluating the mechanical cyclic response to axial compression and tension; (ii) the development of a numerical model for investigating the reproduction of the strong unsymmetrical axial response of the device. The proposed numerical model reposes on a modified form of the Wang and Wen model by supplementing it with user identified scaling functions.

Keywords: *RNC device, seismic isolation, axial response, laboratory, numerical simulations*

Multi-hazard Mitigation of Building Structures using New Floor Isolation Techniques

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ABSTRACT

The design of structures has primarily been geared towards addressing the most dominating hazard at the location of interest. Evidence of global warming and the associated extreme climate conditions, however, have increased the probability of a structure being subjected to different types of extreme demands. As a result, the design philosophy of structures is shifting towards a more holistic approach of addressing multiple hazards to ensure adequate performance under different loading scenarios. This requires the utilization of new structural systems that can sustain only minimal damage under extreme loads. In this paper, two new floor isolation techniques are presented and their main features are discussed. The floor isolation systems are employed in numerical analysis to re-evaluate the response of building systems utilizing these isolation slabs under uncoupled multiple hazards of wind and seismic demands. It is shown that the proposed systems out-perform the response of conventional composite slab buildings.

Keywords: *Multi-hazard, Suspended Slabs, Tuned Mass Damper, Floor Isolation*

Fuzzy-sliding mode supervisory control of an electric seismic shake table

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ABSTRACT

Precise tracking of the earthquake acceleration profile in the presence of uncertainties is a challenge for the shake table control design. Design and implementation of a fuzzy-sliding mode supervisory controller for an electric seismic shake table with variable payload is addressed in this paper. The proposed controller contains two layers including a PI loop and a fuzzy-sliding mode supervisory controller. The controller is then implemented in the shake table and its performance is evaluated via extensive experiments. The test results reveal successful performance of the proposed controller at robust tracking of two sample earthquakes in the presence of parametric uncertainties.

Keywords: *Shake table, earthquake, acceleration tracking, fuzzy- sliding mode, variable payload*

Performance evaluation of a filter-based pseudo-negative stiffness control for seismically isolated structures

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ABSTRACT

Research shown in this paper is focused on the development of a new filter-based pseudo-negative stiffness (FPNS) control algorithm, which aims to overcome the challenge of the sudden change of control force produced by the conventional PNS control force. The strategy of this method is to produce a negative stiffness friction damping force with a gradual change at velocity switches by employing a low-pass filter. By investigating the time-history curves and the hysteresis loops of the FPNS control force, it is found that the low-pass filter also enables the control force at the original position increases with increasing seismic intensities and helps roll off the high-frequency component of the control force. Only the relative displacement of control devices is required for measurement.

A semi-active design is developed to produce the desired reference control force by MR dampers. The structure used for numerical simulation is the base-isolated benchmark building. Seismic responses of the FPNS control, the simple displacement PNS control, the sample semi-active control and the optimal viscous damping control are compared under different seismic intensities. The effectiveness of each control case is evaluated based on the 'ideal isolation control principle'. The results show that the FPNS control can improve the isolation functionality for both low-to-moderate and extreme seismic intensities as well as enhance the isolation safety.

Keywords: *base isolation, pseudo-negative stiffness control, benchmark problem, semi-active control*

Experimental and numerical assessment of a three storey reinforced concrete building submitted to torsion

Pierre-Etienne Charbonnel[1], Benjamin Richard[1], Stefano Cherubini[1]

Abstract

Despite all the efforts made in the field of modeling to describe the behavior of structures, substructures or joints composing complex systems, experimental validation remains, in many cases, the only way to verify the predictivity of the developed models. Earthquake engineering is no exception to this rule: large experimental campaigns are launched on more or less complete civil engineering structures built at full or reduced scale [1]. Given the masses to set in motion and the colossal forces needed to reproduce the seismic input, experimental facilities are mainly composed of hydraulic actuators and the response of the experimental system (including specimen and hydraulic device) constitutes an extremely rich database for validation or model updating.

In this communication, we present results obtained from the SMART2013 test campaign during which a reduced scale three storey reinforced concrete (RC) building was subjected to a dynamic ground motion input by the mean of the 6 degree of freedom AZALEE shaking table of the CEA-TAMARIS facility (see Fig. 1). The specimen, which design has been thought for favoring torsional effects, has been instrumented with more than 200 channels including accelerometers, displacement sensors and strain gauges on the steel bars.

A first part of the work has consisted in identifying the modal signature of the experimental system as a synthetic feature for model validation. Covariance-driven subspace-based identification [2], [3] has been used for tracking the modal signature of the specimen after each one of the eleven damaging seismic inputs. New modal indicators will be presented for the purpose clarifying the stabilization diagrams and helping the automation of the pole selection step. The comparative performances of several algorithms will be given and the evolution of the natural frequencies will be related to physical damages observed on the RC specimen

In addition to this experimantal analysis, a refined numerical model of the whole specimen and shaking table has been implemented using the finite element code [?] developped by the CEA/SEMT. The results of this numerical study (modal signature and time histories) will be presented and compared to experimental database. Finally, the first results using a model updating approach constituting in minimizing an energy based data misfit residual [4] will be given.

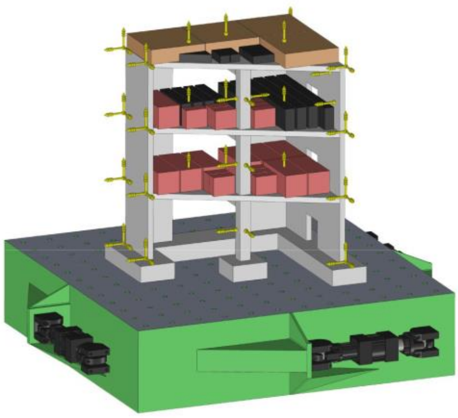

Fig. 1. View of the reduced scale SMART specimen on the 6×6m AZALEE shaking table plate.

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*This work was realized within the framework of the SMART2013 test campaign as part of the "seismic risk" project of the tirpartite institute CEA/EDF/AREVA. and supported by Commissariat l'Energie Atomique et aux Energies Alternatives (CEA) and Electricit de France (EDF) 1CEA, Seismic Mechanics Laboratory – TAMARIS experimentalfacility,91191 Gif-sur-Yvette Cedex, France
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Abstracts

System ID and Nonlinear Systems

Location: Lecture Theatre 4, Diamond Building

Session Chair: J. Mottershead

Tuesday 12th July

Unscented Kalman filter for simultaneous identification of structural parameters and unknown excitations of a building structure

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ABSTRACT

Identification of structural parameters under unknown excitations is an import task in structural health monitoring. This paper presents an efficient algorithm for simultaneously identifying structural parameters of a building structure and unknown excitations based on unscented Kalman filter (UKF). To utilize the UKF method directly, the observation equation of the structural system with unknown excitations is firstly transformed from a multiple linear regression equation to a simple linear regression equation by projecting on to the column space of influence matrix of unknown excitations. Then, an analytical recursive UKF algorithm is developed for identifying unknown excitations and structural parameters such as stiffness and damping. The feasibility and accuracy of the proposed algorithm are finally demonstrated in terms of an example shear building, in which the measurement noise is included. The results clearly exhibit that the proposed algorithm can simultaneously identify unknown excitations and structural parameters efficiently and accurately.

Keywords: *Structural parameters identification; unknown excitations; simultaneous identification; unscented Kalman filter*

Parameter Identification of Hysteresis Using Duffing-Like Model

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ABSTRACT

This paper discusses a relatively new and standard system identification approach for hysteresis system using the Duffing-like model. As well-known in literature, many structural and mechanical components display the hysteresis behaviour of forward-backward loop on the input-output graph, such as magnetorheological damper and rubber isolator. The existing hysteresis models in literature usually involve non-ideal functions, such as coupled parameters and absolute values. Difficult-to- determine parameters sometimes cause the design, analysis, and compensation work inefficient and ineffective for pragmatic purpose. The proposed Duffing-like model is developed based on the Duffing equation, showing a scenario of continuous nonlinear ordinary differential equation. Therefore, the parameters are decoupled and the identification work can be carried out in a more systematic and deterministic manner. In addition, stability of the Duffing-like model can be proven using the Lyapunov and invariant set theorems, which offer a basis for parameter bounding and control design. Modelling and identification results of a magnetoresistive sensor are shown as an example to demonstrate the proposed techniques; the physical meaning of the parameter is also discussed.

Keywords: *Duffing equation, hysteresis, magnetoresistive sensor, system identification*

On the use of black-box tools for backbone curve characterisation

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ABSTRACT

The machine learning methods that are introduced in this work via advanced black-box models, aim to address the problem of validation relating to the modal analysis of nonlinear structures. Modal analysis is an important tool in structural dynamics, as it is used to understand the dynamical characteristics of the structure; however, it is restricted to linear systems. Many methods have been proposed in recent years regarding nonlinear analysis, such as nonlinear normal modes or the method of normal forms that can extract analytic forms of backbone or skeleton curves. The motivation for this paper comes from the problem of how to either interpolate or extrapolate backbone curves in a data-based approach via an unsupervised learning technique. In vibration analysis, the relationship between system resonances and external forcing is particularly important, especially when nonlinearities are present. Using the approach that is proposed here, leads to a simpler form when investigating backbone curves by simulating resonant behaviour without any need of complicated algebraic equations.

Mathematical and numerical evaluation of the damping behaviour for a multi-strand bar

Haval Asker, Jem Rongong, Charles Lord
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ABSTRACT

Multi-strand systems include, but are not limited to, electrical wire conductors, structural cables, and some composite reinforcements. These systems (apart from composite reinforcements) are generally metallic for a variety of reasons. One often overlooked advantage is that dry friction between metal contacts can provide damping over significantly wider temperature ranges than is typical for common damping materials such as viscoelastic polymers. This paper, proposes a mathematical model that describes the hysteretic vibrational behaviour of a frictionally constrained multi-strand bar constructed from strands that have a circular cross-section. The mathematical model analytically predicts the frictional system stiffness under simply supported boundary conditions. The assembled strands are numerically simulated using finite elements and hysteresis behaviour is compared to that obtained from the mathematical model. This shows that the mathematical model is capable of predicting the stiffness and the force-displacement hysteresis response of the system for a variety of conditions.

Active and Semi Active Control

Location: Lecture Theatre 3, Diamond Building

Session Chair: M. Zilletti

Wednesday 13th July

A Method For Computation Of Realizable Optimal Feedback For Semi-Active Controlled Structures

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ABSTRACT

Semi-active control systems provide an attractive solution for the structural control problem. As known, dividing the controller into two components - a damper controller and a system controller simplifies the control law design. The damper controller generates control forces that track some control signal generated by the system controller. A common approach in damper controllers is to use signal clipping whenever the signals generated by the system controller are not realizable due to the physical control limitations. The present study suggests an algorithm for computation of a realizable optimal control feedback, for vibrating structure. The computed control forces are suitable for realization by semi-active dampers controllers without the need for signal clipping. The effectiveness of the suggested method is demonstrated by numerical example.

Keywords: *optimal control, feedback, semi-active structural control, Krotov's method*

Active control of a non-smooth nonlinear system using feedback linearisation

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ABSTRACT

Partial feedback linearisation is applied to an experimental nonlinear non-smooth mechanical system with three degrees of freedom and opening and closing gaps to produce a piecewise-linear stiffness characteristic. Stepped sine testing shows that the second mode is strongly affected by the nonlinearity whereas the first and third modes remain essentially linear. A mathematical model is tuned to accurately reproduce the nonlinear test behaviour, including jump phenomena. The classical theory of feedback linearisation is then briefly reviewed and feedback gains are determined based on the tuned model with the purpose of pole assignment. The zero dynamics are found to be stable. Closed-loop tests are carried out to assign linear viscous damping ratios to the linearised system. These are measured using the logarithmic decrement and found to be in very good agreement with demanded values.

Keywords: *Active control, feedback linearisation, non-smooth nonlinear system, piecewise linearity*

LQR–UKF Semi–Active Control Of Uncertain Structures

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ABSTRACT

A novel semi-active control strategy for the effective vibration mitigation of structural systems of uncertain properties is introduced in this study. The implemented approach emerges through fusion of the Unscented Kalman filter (UKF), as a nonlinear observer, with the linear-quadratic regulator (LQR). The UKF is implemented towards the establishment of an adaptive joint state and parameter estimation problem, taking into account that numerical models of structural systems are often inadequate due to inherent uncertainties, such as noise and modeling errors, unknown system properties and influence of varying operational conditions. The improved state-space representation is accordingly fed into the LQR and a semi-active control scheme that utilizes clipping is applied. Since both estimation and control are executed within the same loop, particular attention is attributed to the derivation of the appropriate LQR strategy, pertaining to both the selection of optimal weight matrices and the real-time tuning of the control parameters. A simulated five-story shear-frame subject to earthquake motion serves as a case-study for validating the proposed methodology. The promising results encourage further investigation of the developed strategy, especially in regards to its real-time experimental implementation using semi-active actuators, such as magnetorheological dampers.

Keywords: *structural control, uncertain system properties, unscented Kalman Filter, real-time LQR, semi-active control.*

A semi-active rocking system for wind turbines under extreme wind loads

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ABSTRACT

In the last decades, the negative impact of the use of fossil fuels on the environment has led to a boom in the production of wind turbines. Then, wind turbine heights are progressively increasing in order to take advantage of the smoother winds at higher altitude. But, this has led to an increased demand to control tower forces. The application of a semi-active (SA) control system is herein proposed and discussed. Its aim is to limit bending moment demand at the base of a wind turbine by relaxing the base restraint of the turbine's tower, without increasing the top displacement, thanks to the sharp increase of dissipated energy in selected intervals of time and a consequent change in tower dynamic properties. The proposed SA control system reproduces a variable restraint at the base that changes in real time its mechanical properties according to the instantaneous response of the turbine's tower. This smart restraint is made of a central smooth hinge, elastic springs and SA magnetorheological dampers driven by a properly designed control algorithm. A commercial 105 m tall wind turbine has been assumed as a case study. Several numerical simulations have been performed with reference to an extreme load, aimed at establishing a procedure for the optimal calibration of the control algorithm according to the specific case, finally proving the actual potential of the proposed control technique in reducing the structural demand with respect to the "fixed base" structure.

Keywords: *Semi-active control, rocking control system, wind turbine, magnetorheological damper*

Abstracts

Special Session: Damping

Location: Lecture Theatre 3, Diamond Building

Session Chair: J. Rongong

Wednesday 13th July

Electromechanical pendulum for vibration control and energy harvesting

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ABSTRACT

This paper presents the design of an experimental electromechanical device for vibration control and energy harvesting. Traditionally, when the broadband resonant response due to a selected mode of a lightly damped structure needs to be controlled a vibration absorber is used. The resonance frequency of the absorber can be chosen to minimise the response of the structure under control. Optimising the damping ratio to achieve this aim also dissipates the most power in the damper, but care must be taken not to exceed the maximum throw of the device at high excitation levels. The absorber may also be mistuned by changes in operation condition and thus underperform. It is thus important to be able to design tuneable vibration absorbers, able to adapt their resonance frequency and their damping ratio depending on the operation condition.

In this paper, an electromechanical device consisting of a pendulum connected to an electrical motor through a gearbox is proposed. It is shown that by shunting the terminal of the device with an appropriate electrical circuit it is possible to control both its resonance frequency and its damping ratio. The power dissipated in the resistive part of the shunt circuit could also be harvested and used to implement the tuning mechanism, or for other purposes.

Keywords: *Tuneable vibration absorber, electromechanical absorber, energy harvesting*

Analysis of multiple-degree-of-freedom systems containing multi-functional friction damper

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ABSTRACT

Friction dampers are one type of energy dissipation devices that are able to forms an efficient seismic protection system for seismic structures. Nevertheless, traditional friction dampers can only be designed under a target earthquake of a given intensity. Complied with the current design code, this target earthquake usually has an intensity of the return period of 475 years. Consequently, traditional friction dampers may function well under earthquakes with the intended design level, but may not be functional for earthquakes with lower intensities. This situation may pose a problem particularly for some functional facilities, which usually contain vibration-sensitive equipment that is vulnerable to earthquakes with moderate intensities. In order to satisfy the aforementioned multiple functional demands, this paper investigates the possible use of a novel multi-functional friction damper (MFD). Different from traditional friction dampers, the MFD has two-stage slip forces that can be activated in a moderate and a strong seismic level, respectively. The theory of the MFD and the formulation of a multiple-degree-of-freedom system with the MFD are both given in this paper. The results of the numerical simulation reveals that the MFD is able to reduce the structural responses under strong and moderate ground motions, simultaneously. In addition, the MFD is also more effective at reducing the structural responses under a moderate earthquake, as compared to the response result from a traditional friction damper.

Keywords: *multi-functional; friction damper; passive control.*

Experimental Study on the Application of Electro-Adhesive Gel Dampers to Base-Isolated Building Using a Small-Scale Specimen

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ABSTRACT

In this study, control methods for a semi-active damper using an electro-adhesive gel (EAG) are analyzed. The modeling of an EAG damper is conducted on the basis of the approximation of the force–voltage relation obtained from experimental data. The performance of an EAG damper is evaluated by shaking-table tests of a two-story small-scale specimen. The specimen is designed to adjust the ratio between the first and second natural periods to that of a target real-scale base-isolated building, and the system parameters are identified on the basis of the vibration response under white noise excitation. An EAG damper is implemented to the base-isolation layer of the small-scale specimen. Acceleration sensors are attached to each layer to acquire the response data. A Kalman filter is employed as an observer in a control system, and the LQG strategy and disturbance accommodating control are advocated as a controller to apply a suitable input voltage to the EAG damper. The cost function of the LQG is formulated to suppress the acceleration response of the specimen. Experiments using other control methods, i.e., the simulated nonlinear spring and the simulated dashpot, are also conducted for comparison. With respect to the input excitation, scaled earthquake ground motion records are used. Based on the results of the shaking-table tests, we report the validity of the EAG damper and discuss effective control methods.

Keywords: *Electro-adhesive gel, Semi-active damper, Semi-active control, Base-isolated building,*

Prestressing for local isolation of forced vibrations

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ABSTRACT

The problem of dynamic response stabilization is a crucial issue in many engineering applications or structures subjected to an external source of excitation or dynamic load. At present, owing predominantly to advances in measurement technology, microprocessor control and development of smart materials it is possible to solve many of these problems. Semi-active or active damping systems, which are used to improving structure response, requires additional dampers or absorbers.

Contrary, in the article we present approach of suppressing local vibration via introducing initial prestressing into the chosen element or elements of the structure. In that way it is possible to change properties of the structure and its modes of vibrations.

We present the results of numerical simulations of the mechanical structure subjected to external excitations. Our results show that by introducing prestressing it is possible to significantly influence on eigenfrequances and eigenmodes. Also effectiveness of vibration amplitudes reduction can be significantly larger, at least one order of magnitude larger.

Keywords: *local suppresion of forced vibrations, prestressing, sensitivity analysis and prestress optimization*

Damping Of Metallic Wool with Embedded Rigid Body Motion Amplifiers

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ABSTRACT

The use of entangled metallic wires as vibrational dampers and shock isolators is of interest in a variety of applications. By taking advantage of the frictional contact between the contiguous wires, it has been shown that significant amounts of energy dissipation can be achieved. The amount of energy dissipation is highly dependent on many factors with one in particular being the excitation amplitude. When the excitation amplitude is low, a combination of the number of contact points, in which have relative motion, and the contact pressure are lessened often leading to a sacrifice in energy dissipation. In this paper, spherical metallic rigid bodies are embedded within metallic wool. These rigid bodies act as motion amplifiers in which, locally within the metallic wool, amplify the excitation amplitude leading to an increase in vibrational damping. Presented are experimental modal results from various metallic wool/embedded rigid body arrangements within a prismatic hollow aluminium tube. It is found that the level of amplification from the embedded rigid bodies depends not only on their size but also their distribution and quantity. An analytical model is proposed which accounts for the wave motion within the metallic wool to estimate the damping effect that this filler material has on the behaviour of the overall structure. The model treats the metallic wool/rigid particle combination as a homogeneous, equivalent solid with amplitude dependent damping properties thereby reducing the complexities of the physics-based model while still providing an estimate of the vibrational damping

Inerters

Location: Lecture Theatre 4, Diamond Building

Session Chair: J. Jolnicki-Szulc

Wednesday 13th July

Investigation Into The Effect Of Device Nonlinearity In Tuned-Inerter-Dampers

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ABSTRACT

This paper investigates the impact of inerter nonlinearities on the performance of tuned- inerter-dampers (TID). The inerter completes the force-current analogy between mechanical and electrical networks, and it represents the mechanical element equivalent to a capacitor. The TID is a vibration suppression system designed to limit unwanted vibrations of civil engineering structures and has a layout similar to that of a tuned-mass-damper (TMD), where the mass element was replaced by an inerter, making it a two-terminal device. The TID offers significant advantages over TMDs, in terms of performance over a wider frequency band, installation and dimensions. Nevertheless, the study carried out to date has been mainly numerical, considering a linear, purely inertial model of the inerter, where the generated force was proportional to the relative acceleration between the devices terminals. In practice, the dynamics of an inerter include nonlinearities, especially at the low frequencies associated with civil engineering applications. Here, the identification of these nonlinearities is done experimentally, based on an off-the- shelf inerter. The structural system, a single-degree-of-freedom host structure with an attached TID, is tested using Real Time Dynamic Substructuring (RTDS). The inerter represents the physical substructure, while the remaining elements of the TID and the host structure form the numerical substructure. This split allows the optimisation of the TID parameters, since the values of the spring and the damper can be changed without altering the experimental setup. In addition, this configuration takes into account the inerters potentially complex dynamics by testing it experimentally together with the characteristics of the host structure. The experimental and numerical results show that with appropriate retuning of the stiffness and damping components of the nonlinear TID system, the performance of the linear TID can be regained.

Keywords: *inerter, dynamic substructuring, vibration suppression*

Control of across-wind vortex shedding induced vibrations in tall buildings using the tuned mass-damper-inerter (TMDI)

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ABSTRACT

In this paper, the effectiveness of the tuned mass-damper-inerter (TMDI) vis-à-vis the classical tuned mass-damper (TMD) is assessed to suppress vortex shedding induced vibrations to tall building structures in the across-wind direction. The TMDI, previously proposed in the literature to mitigate earthquake-induced vibrations in multi-storey buildings, benefits from the mass amplification effect of the inerter (i.e., a two-terminal device developing a resisting force proportional to the relative acceleration of its terminals by the inertance constant) to achieve improved vibration suppression performance from the classical TMD for the same attached mass. Herein, a linear reduced-order structural system is developed, defined by a diagonal mass matrix and full damping and stiffness matrices, which captures faithfully the dynamic properties of a detailed finite element model corresponding to a benchmark 74-storey building with square floor plan. A TMDI is added to the structural system by elementary operations to the mass, damping, and stiffness matrices under the assumption of an ideal linear inerter. The wind action is represented by an analytical spectral density matrix modelling correlated across-wind induced forces accounting for vortex shedding and the structural analysis step is undertaken in the frequency domain for efficiency. A comprehensive parametric analysis is undertaken demonstrating that the TMDI achieves better performance in terms of peak top floor acceleration reduction with increasing inertance than a classical TMD with the same attached mass. This is also true for relatively small attached masses of practical interest to tall buildings (less than 0.5% the total buildings mass) for the case of peak top floor displacements. Further, it is shown that the TMDI reduces significantly the peak attached mass displacement, while the peak developing forces at the inerter are not excessive and can be locally accommodated by the building.

Keywords: *Tall buildings, vortex shedding, tuned mass damper, inerter, wind*

Passive Vibration Suppression Using Multiple Inerter-Based Devices For A Multi-Storey Building Structure

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Department of Mechanical Engineering, University of Bristol, UK

ABSTRACT

This paper investigates the application of multiple passive absorbers incorporating inert- er(s), spring(s) and damper(s) to suppress vibrations in a multi-story structure. Different from the one terminal mass element, the inerter was proposed as a two-terminal element, with the property that the ap- plied force is proportional to the relative acceleration across its terminals. The device can be configured to include gearing, hence allowing a far higher inertence than device mass. The advantage of using a TID as a suppression device mounted at the bottom of a multi-storey building has been identified. In this paper, a five-storey building model with two TIDs subjected to the base excitation is studied. Both of these devices are located at the bottom. The criterion selected for the optimisation is the minimisation of the maximum relative displacement of the building. Furthermore, the resulting structural responses are compared to the case where a single TID is used at the bottom, to show the potential benefits that arise from using multiple devices. In addition, we show that the resulting optimal inertance needed for each device is smaller compared to the case where a single TID is used between the ground and the first floor, which makes the suppression system easier to manufacture.

Keywords: *Multiple passive vibration suppression, relative displacement, base excitation, inerter*

A FLUID INERTER WITH VARIABLE INERTANCE PROPERTIES

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ABSTRACT

The inerter is a novel dynamic device that is the subject of substantial research interest as a passive vibration control device. In this paper we present results from the design and testing of a novel type of fluid inerter system where the inertance can be varied. This variable inertance is achieved by having a fluid filled cylinder that induces flow in a helical pipe system. The parameters of the helical pipe system can be adjusted to give different amounts of inertial force depending on the requirements. Tests were carried out on the inerter system, and it was shown that with the maximum inertance set-up for this system, the sensitivity of output force to input velocity was approximately 500N force for a 1Hz increase in excitation frequency.

KEYWORDS: *Fluid inerter, passive control, experimental tests.*

Resonant Inerter Based Absorbers for a Selected Global Mode

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Abstract

A common problem in damping/control of structures is to introduce damping into a selected vibration mode by application of of a resonant vibration mechanical or electro-mechanical absorber device. The problem is here illustrated in Fig. 1 illustrating a structure equipped with a resonant inerter based device, shown in detail in the right figure. The present paper describes a calibration procedure, valid for several different resonant device configurations based on a stiffness k_d, a damper c_d, and an inerter element m_d.

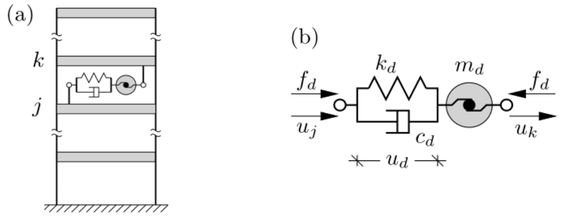

Figure 1. a) Structure with resonant inerter device, b) resonant inerter-based absorber.

A key point is an approximate representation of the displacement u of the structure across the two poles of the device and the associated force f through the device. Typically, the targeted resonant mode, denoted by the subscript r, gives a modal response, plus quasi-dynamic contributions from other non-resonant modes. This displacement corresponds to that over the device, expressed in terms of the device frequency response function $H_d(\omega)$. The difference between the two displacements then take the form

$$u_s - u_d \simeq \Big[\underbrace{\frac{\omega_r^2}{\omega_r^2 - \omega^2}\frac{1}{k_r} + \frac{1}{k_r'} - \frac{1}{m_r'}\frac{1}{\omega^2}}_{\text{flexible structure}} + \underbrace{H_d(\omega)}_{\text{device}} \Big] f. \tag{1}$$

The calibration procedure is based on equivalence with the ideal case, in which there is no local flexibility or local inertia in the structural response, i.e. the case of single mode response. This case is easily solved from the characteristic equation by the 'equal modal damping' procedure.

The calibration of the general case is then obtained by rearranging the response relation (1) in the form

$$u_s - u_d \simeq \Big[\underbrace{\frac{\omega_r^2}{\omega_r^2 - \omega^2}\frac{1}{k_r}}_{\text{ideal structure}} + \underbrace{H_d'(\omega)}_{\text{equivalent device}} \Big] f. \tag{2}$$

where the local flexibility and inertia terms are absorbed into an equivalent device response function $H_d'(\omega)$.

Three device types are analyzed: full series coupling, and the damper either in parallel with the stiffness or the inerter. Each represents a viable design with an near-flat plateau of the frequency response curve; but the full series design requires a larger device damping coefficient.

References

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Abstracts

Inerters/Active TMD

Location: Lecture Theatre 4, Diamond Building

Session Chair: S. Neild

Wednesday 13th July

Shaking Table Tests of Cooperative Control between an Active Mass Damper for a Building and Semi-Active Damper for a Base-Isolated Floor Using a Small-Scale Specimen

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ABSTRACT

To reduce the amount of earthquake damage, the effectiveness of cooperative control between two controllers (one for the building and another for the equipment) was verified using a shaking table test. We employed a Kalman filter and the linear quadratic Gaussian strategy to minimise the amount of damage under strong ground motions, and the two controllers share the quantities of the state variables of the building and equipment. A three-storey specimen, which comprise a building (the main system) with an active mass damper and a base-isolated floor (a subsystem) with a semi-active oil damper, represents a 15-storey building of a data centre on a real scale. As a result of the shaking table test, we confirmed that implementing cooperative control reduced the relative displacement between the main system and subsystem without increasing absolute acceleration.

Keywords: *Base isolation, Semi-Active control, Vibration control, Seismic response, Earthquake*

Robust reliability-based design of seismically excited tuned mass-damper-inerter (TMDI) equipped MDOF structures with uncertain properties

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ABSTRACT

This paper considers a reliability-based approach for the optimal design of the tuned mass-damper-inerter (TMDI) in linear building frames with uncertain structural properties subject to seismic excitations defined as stationary colored random processes with uncertain parameters. The TMDI is a recently introduced generalization of the classical linear passive tuned mass-damper (TMD) comprising an additional mass attached to the primary structure whose oscillations are to be suppressed via a linear spring and dashpot in parallel. The TMDI benefits from the mass amplification property, the so-called inertance, of an inerter device that links the additional mass to a different floor from the one it is attached to which improves the vibration suppression capabilities of the TMD. Herein, the structural seismic performance is quantified through the probability of occurrence of different failure modes, related to the floor acceleration, the interstorey drifts, and the attached mass displacement exceeding acceptable thresholds. The overall design objective is taken as a linear combination of these probabilities whereas the TMDI linear spring constant, viscous damping constant, and inertance properties are taken as the design variables. The parametric structural and excitation uncertainty is efficiently addressed through a two-stage approach combining a Taylor series approximation and Monte Carlo simulation. Numerical data for a 10-storey shear frame structure equipped with a TMDI with different values of attached mass and arranged in 8 different topologies are furnished indicating the enhanced performance of the TMDI over the classical TMD for relatively small attached masses. The reported numerical results evidence that the performance of optimally designed TMDIs is less affected by the parametric uncertainties as the total inertia TMDI properties (attached mass and inertance) increases, indicating that the inclusion of the inerter leads to more robust passive vibration control.

Keywords: *Tuned mass damper, inerter, reliability, model uncertainty, stochastic optimization, earthquake*

Performance Assessment Of A Novel Energy Harvesting-Enabled Tuned Mass-Damper-Inerter (EH-TMDI) For White Noise-Excited Structures

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ABSTRACT

In this paper the potential of a novel dynamic vibration absorber termed energy harvesting-enabled tuned mass-damper-inerter (EH-TMDI) is assessed for simultaneous vibration suppression and power generation in white-noise force- and base acceleration-excited structures modelled as damped single-degree-of-freedom (SDOF) oscillators. The considered EH-TMDI comprises a classical linear TMD incorporating an electromagnetic energy harvester connected in series with an inerter device to link the attached TMD mass to the ground in a sky-hook configuration. Pertinent frequency response functions are analytically derived from the underlying equations of motion of EH-TMDI-equipped SDOF primary structures as functions of a number of dimensionless parameters associated with the mechanical properties of the EH-TMDI device and the primary structure. It is shown through appropriate parametric analyses that by varying the mass amplification constant of the inerter device and by adjusting stiffness and damping properties of the TMD using standard optimum TMD design formulae, enhanced vibration suppression (in terms of deflection variance of the primary structure) and energy harvesting (in terms of relative velocity variance at the terminals of the harvester) may be achieved simultaneously for a fixed attached TMD mass. Overall, the herein reported analytical data and parametric analysis point to the fact that the EH-TMDI is amenable to a meaning- ful multi-objective optimum design, which may simultaneously minimise the primary structure oscillations and maximise power generation.

Keywords: *Tuned Mass Damper, Inerter, Energy Harvesting, White-Noise Excitation.*

Investigation of Size Effect on Control Performance of Tuned Liquid Dampers by using Real-Time Hybrid Simulation

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ABSTRACT

Tuned liquid damper (TLD), as a low cost and maintenance energy-absorbing device, is an effective passive control technique to suppress structural vibration under wind and seismic loads. The dynamic characteristic of TLD is highly dependent on its geometric sizes as well as liquid volumes. Hence, the relationship between control performance and TLD sizes is critical to the optimization of TLD design. Due to its strongly nonlinear behaviour, experiments rather than pure numerical simulations may be more reasonable to evaluate dynamic responses of structure-TLD systems. In this paper, the real-time hybrid simulation (RTHS) is employed to investigate the size effect of TLD on control efficiency, in which TLD devices, with varied geometric sizes, are experimentally modelled as physical substructures, and controlled structures are numerically simulated as numerical substructures. A series of RTHSs are carried out with the premise of same controlled structures as well as mass ratio; and the variation of mass scale is also taken into account. Results show that the TLD performance is size- dependent; a shallow liquid in TLD with lower relative liquid depth may be more efficient on both peak and RMS responses control. Experiments with scaled TLD models will overestimate the control performance of prototype TLD devices, indicating that full-scale TLD experiments should be pursued.

Keywords: *Tuned liquid damper; Real-time hybrid simulation; Size effect; Control efficiency; Mass scale*

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