Proceedings of the
Ninth International Conference on
Computational Structures Technology

Civil-Comp Press publications on Computational Engineering

Proceedings of the Eleventh International Conference on Civil, Structural and Environmental Engineering Computing
Edited by: B.H.V. Topping

Proceedings of the Ninth International Conference on the Application of Artificial Intelligence to Civil, Structural and Environmental Engineering
Edited by: B.H.V. Topping

Proceedings of the Fifteenth UK Conference of the Association of Computational Mechanics in Engineering
Edited by: B.H.V. Topping

Proceedings of the Eighth International Conference on Computational Structures Technology
Edited by: B.H.V. Topping, G. Montero & R. Montenegro

Proceedings of the Fifth International Conference on Engineering Computational Technology
Edited by: B.H.V. Topping, G. Montero & R. Montenegro

Saxe-Coburg Publications on Computational Engineering

Computational Methods for Acoustics Problems
Edited by: F. Magoulès

Mesh Partitioning Techniques and Domain Decomposition Methods
Edited by: F. Magoulès

Object Oriented Methods and Finite Element Analysis
R.I. Mackie

Programming Distributed Finite Element Analysis
R.I. Mackie

Computer Aided Design of Cable-Membrane Structures
B.H.V. Topping and P. Iványi

Domain Decomposition Methods for Distributed Computing
J. Kruis

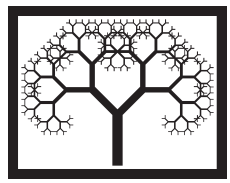
Computational Modelling of Masonry, Brickwork and Blockwork Structures
Edited by: J.W. Bull

Finite Element Mesh Generation
B.H.V. Topping, J. Muylle, P. Iványi, R. Putanowicz and B. Cheng

Civil Engineering Computations: Tools and Techniques
Edited by: B.H.V. Topping

Proceedings of the Ninth International Conference on Computational Structures Technology

Edited by
B.H.V. Topping and M. Papadrakakis



CIVIL-COMP PRESS

published 2008 by
Civil-Comp Press
Dun Eaglais, Kippen
Stirlingshire, FK8 3DY, UK

Civil-Comp Press is an imprint of Civil-Comp Ltd

ISBN 978-1-905088-21-8 (Book)
ISBN 978-1-905088-22-5 (CD-Rom)
ISBN 978-1-905088-23-2 (Combined Set)

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Cover Image: mesh created by R. Montenegro and G. Montero based on the "25 Years of Civil-Comp Conferences" logo.

Printed in Great Britain by Bell & Bain Ltd, Glasgow

Contents

Mechanics of Composites, Functionally Graded and Piezoelectric Materials
Session organised by T. Kant

Spectral and Wave Element Methods for Structural Response Prediction and Damage Detection
Session organised by J.R. Arruda

Soft Computing and Structural Engineering
Session organised by Y. Tsompanakis and N. Lagaros

Differential Quadrature, Generalized Methods and Related Discrete Element Analysis Methods
Session organised by C.N. Chen

Application of Finite Element Methods for the Analysis and Design of Steel and Concrete Structures
Session organised by E.S. Mistakidis

Structural Analysis and Optimization in Acoustics and Vibrations
Session organised by M. Matos Neves and J.F. Aguilar Madeira

Probabilistic Approaches and Optimisation for Structural Mechanics
Session organised by A. Elhami and M. Karama

Damage Identification
Session organised by C.A. Papadopoulos

Damage and Identification Problems

Shakedown Analysis and Design

Analysis of Trusses, Frames and Space Structures

Probabilistic Engineering Problems

Dynamics and Vibration

Passive Damping Systems

Seismic Engineering

Composite Materials

Preface

This volume comprises the summaries of contributed papers presented at The Ninth International Conference on Computational Structures Technology (CST 2008) held in Athens, Greece from 2 to 5 September 2008. The full papers from the conference are available on the accompanying CD-ROM. The CST conference series began in Edinburgh during 1991. The 2008 conference was held concurrently with The Sixth International Conference on Engineering Computational Technology (ECT 2008).

The special sessions included in this volume of Proceedings are:

- Modeling and Simulation of Composite and Adaptive Structures
  organised by C.M. Mota Soares
- Multi-Scale Numerical Modeling of Engineering Structures
  organised by J.Q. Ye and Y. Sheng
- Numerical Design of Protective Structures
  organised by N. Gebbeken
- Modelling of Composite Beams
  organised by J. Murin
- Mechanics of Composites, Functionally Graded and Piezoelectric Materials
  organised by T. Kant
- Spectral and Wave Element Methods for Structural Response Prediction and Damage Detection
  organised by J.R. Arruda
- Evolutionary and Non-Deterministic Methods in Structural Optimization
  organised by M. Domaszewski
- Stochastic Optimization Methods in Structural Analysis and Optimal Design
  organised by K. Marti and G.I. Schuëller
- Soft Computing and Structural Engineering
  organised by Y. Tsompanakis and N. Lagaros
- Differential Quadrature, Generalized Methods and Related Discrete Element Analysis Methods
  organised by C.N. Chen
- Application of Finite Element Methods for the Analysis and Design of Steel and Concrete Structures
  organised by E.S. Mistakidis
- Structural Analysis and Optimization in Acoustics and Vibrations
  organised by M. Matos Neves and J.F. Aguilar Madeira
- Probabilistic Approaches and Optimisation for Structural Mechanics
  organised by A. Elhami and M. Karama
- Damage Identification
  organised by C.A. Papadopoulos
- Computational Tools for Earthquake and Structural Dynamics
  organised by S.H. Lo
- Non-Linear Dynamics
  organised by M. Amabili

We are particularly grateful to the organisers of these special sessions.

The following sessions are also included in this volume:

- Finite Element Methods
- Finite Elements: Plasticity
- Finite Elements: Modelling and Design
- Boundary Element Methods
- Plate Problems
- Damage and Identification Problems
- Shakedown Analysis and Design
- Analysis of Trusses, Frames and Space Structures
- Structural Optimization
- Shape and Topology Optimization
- Reliability Design
- Reliability Analysis and Modelling
- Probabilistic Engineering Problems
- Dynamics and Vibration
- Passive Damping Systems
- Seismic Engineering
- Wave Propagation Problems
- Contact-Impact Problems
- Steel Structures
- Reinforced Concrete Structures: Design
- Reinforced Concrete: Analysis
- Fibre Reinforced Concrete
- Shell Structures
- Masonry Structures
- Crack Propagation: Modelling
- Timber Structures
- Microstructures: Analysis and Modelling
- Polyethylene Materials
- Constitutive Modelling
- Materials Modelling
- Materials Modelling: Concrete
- Space Structures
- Cable-Net, Cable and Tension Structures
- Offshore Structures
- Automotive Engineering
- Pavement Analysis and Design
- Fire Safety Engineering
- Bridge Engineering
- Building Analysis and Design
- Modelling Retrofitted and Repaired Structures
- Composite Structures
- Composites: Damage Modelling
- Composite Materials

Other papers presented at the conferences in 2008 are published as follows:

- *The Invited Lectures from CST 2008 are published in:*
  Trends in Computational Structures Technology, B.H.V. Topping and M. Papadrakakis, (Editors), Saxe-Coburg Publications, Stirlingshire, Scotland, 2008.
- *The Invited Lectures from ECT 2008 are published in:*
  Trends in Engineering Computational Technology, M. Papadrakakis and B.H.V. Topping, (Editors), Saxe-Coburg Publications, Stirlingshire, Scotland, 2008.
- *The Contributed Papers from ECT 2008 are published in:*
  Proceedings of the Sixth International Conference on Engineering Computational Technology, M. Papadrakakis and B.H.V. Topping, (Editor), (Book of Summaries and CD-ROM), Civil-Comp Press, Stirlingshire, Scotland, 2008.

We should like to thank the members of the CST 2008 Conference Editorial Board for their help before and during the conference: Prof. H. Adeli, USA; Prof. S. Adhikari, UK; Prof. J.F. Aguilar Madeira, Portugal; Prof. M. Amabili, Italy; Prof. T. Aoki, Japan; Dr R. Ardito, Italy; Prof. A.J. Aref, USA; Prof. F. Armero, USA; Prof. J.R. Arruda, Brazil; Dr A.F. Ashour, UK; Prof. H. Askes, UK; Prof. N.O. Attoh-Okine, USA; Dr C.E. Augarde, UK; Prof. J. Awrejcewicz, Poland; Dr A. Bahreininejad, Iran; Prof. C.C. Baniotopoulos, Greece; Prof. A. Baratta, Italy; Prof. H.J.C. Barbosa, Brazil; Assoc. Prof. E. Barkanov, Latvia; Prof. R.C. Barros, Portugal; Prof. K.J. Bathe, USA; Prof. Z.P. Bazant, USA; Prof. A.A. Becker, UK; Prof. T. Belytschko, USA; Prof. A. Benjeddou, France; Prof. N. Bicanic, UK; Prof. M.L. Bittencourt, Brazil; Prof. Z. Bittnar, Czech Republic; Dr J. Blachut, UK; Prof. D. Boffi, Italy; Prof. P. Boisse, France; Prof. M. Bonnet, France; Prof. F. Bontempi, Italy; Assoc. Prof. B. Boroomand, Iran; Prof. Ph. Bouillard, Belgium; Prof. M.A. Bradford, Australia; Dr M. Brunig, Germany; Dr J.W. Bull, UK; Dr C. Butenweg, Germany; Prof. F. Buyle-Bodin, France; Prof. D. Camotim, Portugal; Prof. E. Carrera, Italy; Prof. F. Casciati, Italy; Prof. G. Cederbaum, Israel; Prof. J.M.A. Cesar de Sa, Portugal; Prof. A.H.C. Chan, UK; Dr S. Chandra, India; Prof. C.-N. Chen, Taiwan; Prof. W.F. Chen, USA; Prof. G.D. Cheng, China; Prof. R.C. Cheng, USA; Prof. G. Chiandussi, Italy; Prof. C. Cinquini, Italy; Prof. H.B. Coda, Brazil; Prof. J.Y. Cognard, France; Prof. G.J. Creus, Brazil; Prof. M. Cuomo, Italy; Prof. V.D. da Silva, Portugal; Prof. S. De, USA; Prof. R. de Borst, Netherlands; Prof. J.A.T. de Freitas, Portugal; Prof. G. De Roeck, Belgium; Prof. G. de Saxca'e, France; Dr Z. Dimitrovová, Portugal Prof. I. Doltsinis, Germany; Prof. M. Domaszewski, France; Dr J. Dominguez, Spain; Prof. J. Duane, USA; Prof. L. Dunai, Hungary; Prof. J. Eberhardsteiner, Austria; Prof. A. El-Hami, France; Prof. A. Eriksson, Sweden; Dr D. Eyheramendy, France; Dr P. Fanning, Ireland; Prof. C.A. Felippa, USA; Prof. M. Fivel, France; Prof. D.M. Frangopol, USA; Prof. M.I. Friswell, UK; Prof. G. Gambolati, Italy; Prof. L. Gastaldi, Italy; Prof. V. Gattulli, Italy; Prof. Dr-Ing. N. Gebbeken, Germany; Prof. J.-C. Gelin, France; Prof. R.G. Ghanem, USA; Prof. R.I. Gilbert, Australia; Prof. D. Givoli, Israel; Prof. P. Gosling, UK; Prof. R.V. Grandhi, USA; Prof. D.E. Grierson, Canada; Prof. A.A. Groenwold, South Africa; Dr Z.W. Guan, UK; Prof. R.M. Guedes, Portugal; Prof. I. Hagiwara, Japan; Prof. P. Hajela, USA; Prof. P. Hamelin, France; Prof. H.-J. Hardtke, Germany; Prof. R. Harte, Germany; Prof. G.R. Heppler, USA; Prof. G. Hofstetter, Austria; Prof. O.S. Hopperstad, Norway; Prof. T.J.R. Hughes, USA; Dr L. Iannucci, UK; Prof. A. Ibrahimbegovic, France; Prof. N. Inoue, Japan; Dr I. Iskhakov, Israel; Prof. A. Ivankovic, Ireland; Dr P. Ivanyi, Hungary; Prof. B.A. Izzuddin, UK; Prof. M. Jirasek, Czech Republic; Prof. M. Kaliske, Germany; Dr E.S. Kameshki, Bahrain; Dr M. Kaminski, Poland; Prof. T. Kant, India; Prof. J.D. Kaplunov, UK; Prof. D.L. Karabalis, Greece; Prof. M. Karama, France; Prof. J.T. Katsikadelis, Greece; Prof. A. Kaveh, Iran; Dr D. Kennedy, UK; Dr A.I. Khan, Australia; Prof. P.H. Kirkegaard, Denmark; Prof. U. Kirsch, Israel; Prof. M. Kleiber, Poland; Prof. L.Yu. Kossovich, Russia; Prof. M.D. Kotsovos, Greece; Prof. W.B. Kraetzig, Germany; Dr J. Kruis, Czech Republic; Prof. H.G. Kwak, Korea; Dr A.S.K. Kwan, UK; Prof. Y.W. Kwon, USA; Prof. R. Lackner, Germany; Prof. P. Ladeveze, France; Dr N. Lagaros, Greece; Prof. K.L. Lawrence, USA; Prof. D. Le Houédec, France; Dr C.K. Lee, Singapore; Dr C.J. Leo,

Australia; Prof. A.Y.T. Leung, Hong Kong; Prof. R. Levy, Israel; Prof. R. Lewandowski, Poland; Prof. R.W. Lewis, UK; Prof. J.Y.R. Liew, Singapore; Prof. K.M. Liew, Hong Kong; Prof. A. Liolios, Greece; Prof. S.H. Lo, Hong Kong; Prof. J. Logo, Hungary; Dr P.B. Lourenco, Portugal; Prof. J. Lu, USA; Prof. R. Mahnken, Germany; Prof. C.E. Majorana, Italy; Prof. H.A. Mang, Austria; Prof. Dr K. Marti, Germany; Prof. M. Matos Neves, Portugal; Prof. K. Maute, USA; Prof. I.M. May, UK; Prof. F.M. Mazzolani, Italy; Dr C.T. Mc Carthy, Ireland; Prof. T.J. McCarthy, Australia; Prof. G. McClure, Canada; Dr G. Mejak, Slovenia; Prof. C. Meyer, USA; Dr G. Milani, Italy; Assoc. Prof. E.S. Mistakidis, Greece; Prof. A. Miyamoto, Japan; Prof. F.J. Montans, Spain; Prof. C.A. Mota Soares, Portugal; Prof. C.M. Mota Soares, Portugal; Prof. J. Murin, Slovakia; Prof. G. Muscolino, Italy; Prof. J.-P. Muzeau, France; Prof. C. Navarro, Spain; Dr L.A.C. Neves, Portugal; Prof. L.F. Costa Neves, Portugal; Prof. G.P. Nikishkov, Japan; Prof. R. Ohayon, France; Prof. E. Oñate, Spain; Prof. C.A. Papadopoulos, Greece; Prof. M. Papadrakakis, Greece; Prof. P.Y. Papalambros, USA; Dr B. Patzak, Czech Republic; Prof. M.N. Pavlovic, UK; Dr C. Pearce, UK; Prof. S. Pellegrino, UK; Prof. J. Petrolito, Australia; Prof. Y. Petryna, Germany; Dr J. Plesek, Czech Republic; Prof. M. Potier-Ferry, France; Assoc Prof. Ch. G. Provatidis, Greece; Prof. C.P. Providakis, Greece; Dr O.M. Querin, England; Prof. C.V. Ramakrishnan, India; Prof. F.G. Rammerstorfer, Austria; Prof. O. Rand, Israel; Prof. E. Rank, Germany; Prof. M. Raoof, UK; Prof. B.D. Reddy, South Africa; Dr Y. Ribakov, Israel; Dr P. Ribeiro, Portugal; Dr A. Riccio, Italy; Prof. H. Rodrigues, Portugal; Prof. Dr-Ing. habil R. Rolfes, Germany; Prof. C.T.F. Ross, UK; Prof. G. Rozvany, Hungary; Dr D. Rypl, Czech Republic; Prof. E. Sacco, Italy; Prof. M. Saje, Slovenia; Prof. E. Salajegheh, Iran; Prof. L.M. Santos Castro, Portugal; Assoc. Prof. E.J. Sapountzakis, Greece; Prof. E. Schnack, Germany; Prof. B. Schrefler, Italy; Prof. G.I. Schuëller, Austria; Prof. K. Schweizerhof, Germany; Dr O. Shai, Israel; Prof. S.K. Sharan, Canada; Dr M.H.B.M. Shariff, UAE; Dr Y. Sheng, UK; Dr R.C. Silva, Brazil; Prof. L. Simoni, Italy; Prof. S.W. Sloan, Australia; Prof. J.D. Sorensen, Denmark; Prof. J.E. Souza de Cursi, France; Prof. E. Spacone, Italy; Dr R. Spallino, Germany; Prof. E. Stein, Germany; Prof. B. Stok, Slovenia; Prof. Y. Sugiyama, Japan; Dr C.C. Swan, USA; Prof. B.A. Szabo, USA; Prof. K.Y. Sze, Hong Kong; Dr K. Tai, Singapore; Prof. I. Takahashi, Japan; Prof. I. Takewaki, Japan; Prof. S. Tanaka, Japan; Prof. T. Tarnai, Hungary; Prof. J.W. Tedesco, USA; Dr A. Tessler, USA; Prof. G. Thierauf, Germany; Prof. R. Tinawi, Canada; Prof. B.H.V. Topping, UK; Prof. V.V. Toropov, UK; Dr J. Trevelyan, UK; Prof. G. Tsamasphyros, Greece; Asst. Prof. Y. Tsompanakis, Greece; Dr G.J. Turvey, UK; Prof. V. Tvergaard, Denmark; Prof. R. Veldman, USA; Prof. P. Venini, Italy; Prof. W. Wagner, Germany; Prof. X. Wang, USA; Prof. N.-E. Wiberg, Sweden; Prof. M. Wiercigroch, UK; Prof. K.S. Woo, Korea; Prof. W. Wunderlich, Germany; Dr J.R. Xiao, USA; Dr Q. Xiao, UK; Dr R.Y. Xiao, UK; Prof. Y.M. Xie, Australia; Prof. Y.-B. Yang, Taiwan; Dr J.Q. Ye, UK; and Prof. A. Zingoni, South Africa.

Finally, we are grateful to Jelle Muylle for designing these conference proceedings and for all his administrative and organisational skills in organising these conferences. We also wish to thank Dawn Sewell (Civil-Comp Press) and Jenny Mitsoura (National Technical University of Athens) for their administrative support before and during the conference.

Prof. B.H.V. Topping
Heriot-Watt University, Edinburgh, UK
& University of Pécs, Hungary

Prof. M. Papadrakakis
National Technical University of Athens, Greece