ADVANCES IN ANALYSIS AND DESIGN OF COMPOSITES

# ADVANCES IN ANALYSIS AND DESIGN OF COMPOSITES

Edited by B.H.V. Topping



**CIVIL-COMP PRESS** 

**CIVIL-COMP PRESS** 10 Saxe-Coburg Place Edinburgh, EH3 5BR, UK

**CIVIL-COMP PRESS** is an imprint of Civil-Comp Limited

© 1996, Civil-Comp Limited

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 0-948749-43-1

Printed in the Scottish Borders by MEIGLE PRINTERS LIMITED Galashiels, Scotland

# **CONTENTS**

# **1. ANALYSIS OF COMPOSITES**

# 2. LAMINATION MODELS

# **3. DELAMINATION MODELS**

# 4. SANDWICH COMPOSITES

# 5. DESIGN AND ANALYSIS OF COMPOSITES

#### 6. DYNAMIC ANALYSIS

#### 7. ANALYSIS OF REINFORCED CONCRETE STRUCTURES

# 8. OPTIMAL DESIGN OF COMPOSITIES

# **\*PREFACE**\*

This volume contains a selection of papers presented at *The Third International Conference in Computational Structures Technology*, held in Budapest from 21st August-23rd August 1996. The papers in this volume include the following topics: Analysis of Composites; Lamination Models; Sandwich Composites; Analysis and Design of Composites; Dynamic Analysis of Composites; Analysis of Reinforced Concrete Structures; and Optimal Design of Composites. Other papers from the conference are published in:

- Advances in Computational Structures Technology Civil-Comp Press, 1996, ISBN 0-948749-40-7
- Advances in Finite Element Technology Civil-Comp Press, 1996, ISBN 0-948749-41-5
- Advances in Optimization for Structural Engineering Civil-Comp Press, 1996, ISBN 0-948749-42-3
- Advances in Computational Methods for Simulation Civil-Comp Press, 1996, ISBN 0-948749-44-X
- Advances in Computational Techniques for Structural Engineering Civil-Comp Press, 1996, ISBN 0-948749-45-8
- Advances in Boundary Element Methods Civil-Comp Press, 1996, ISBN 0-948749-46-6

I should like to thank all the authors for their contributions and in particular those who presented their papers in Budapest. I must also thank the members of the Conference Editorial Board who helped in many ways before and during the conference. The members of the Editorial Board for Computational Structures Technology Conference 1996, were: Professor H. Adeli, USA, Professor N. Akkas, Turkey, Professor E. Alarcon, Spain, Professor J. Argyris, Germany, Professor O. Axelsson, The Netherlands, Professor K.J. Bathe, USA, Dr L. Berke, USA, Professor H.J.C. Barbosa, Brazil, Professor J.W. Baugh, USA, Professor T. Belytschko, USA, Professor P.G. Bergan, Norway, Professor D. Beskos, Greece, Professor P. Bettes, UK, Professor N. Bicanic, UK, Professor R.I. Borja, USA, Professor F. Brezzi, Italy, Dr John W. Bull, UK, Professor C. Cinquini, Italy, Dr. A.H.C. Chan, UK, Professor I. St Doltsinis, Germany, Professor I.S. Duff, UK and France, Dr L. Dunai, Hungary, Professor A. Eriksson, Sweden, Professor D. Frangopol, USA, Professor J.A. Teixeira de Freitas, Portugal, Professor F. Frey, Switzerland, Professor R. Fruchter, USA, Professor M.B. Fuchs, Israel, Professor G. Gambolati, Italy, Professor M. Geradin, Belgium, Professor D.E. Grierson, Canada, Professor D. Hartmann, Germany, Professor P. Hajela, USA, Professor E. Hinton, UK, Professor M.A. Hogge, Belgium, Professor T.J.R. Hughes, USA, Professor M. Ivanyi, Hungary, Professor W.M. Jenkins, UK, Dr P.K. Jimack, UK, Professor S. Kaliszky, Hungary, Professor D.I. Karabalis, USA, Professor A. Kaveh, Iran, T. Kenny, UK, Dr A.I. Khan, Australia, Professor N. Kikuchi, USA, Professor U. Kirsch, Israel, Professor Dr M. Kleiber, Poland, Professor V.K. Koumousis, Greece, Professor W.B. Kratzig, Germany, Professor P. Ladeveze, France, Professor K.L. Lawrence, USA, Dr. S.H. Lee, USA, Professor P. Leger, Canada, Professor A.Y.T. Leung, Hong Kong, Dr. R. Levy, Israel, Professor A. Liolios, Greece, Professor W.K. Liu, USA, J. Mackerle, Sweden, Professor G. Maier, Italy, Professor J. Mandel, USA, Professor H.A. Mang, Austria, Professor I.M. May, UK, Dr J.J. McKeown, UK, Professor J.L. Meek, Australia, Dr H.P. Mlejnek, Germany, Professor G. Molnarka, Hungary, Professor C.A. Mota Soares, Portugal, Dr D.T. Nguyen, USA, Professor A. K. Noor, USA, Professor R. Ohayon, France, Professor E. Onate, Spain, Dr K. Orsborn, Sweden, Professor D.R.J. Owen, UK, Professor M. Papadrakakis, Greece, Professor P.Y. Papalambros, USA, Professor K.C. Park, USA, Professor D. Parsons, USA, Dr. M.N. Pavlovic, UK, Professor M.S. Pereira, Portugal, Dr V.K. Peshkam, UK, Professor E. Ramm, Germany, Professor F. Rammerstorfer, Austria, Professor G. De Roeck, Belgium, Professor A. Samartin, Spain, Professor B. Schrefler, Italy, Professor K. Sweitzerhof, Germany, Dr. G.M. Seed, UK, Professor N. Schiraishi, Japan, Dr. H.D. Simon, USA, Professor G.S. Springer, USA, Dr. I. Sobieski, USA, Professor K.S. Surana, USA, Professor C.A. Syrmakezis, Greece, Professor B.A. Szabo, USA, Professor R. Szilard, USA, Professor G Thierauf, Germany, Dr G. Turvey, UK, Professor Y. Ueda, Japan, Dr G. Vanderplaats, USA, Dr V.B. Venkayya, USA, Professor K.S. Virdi, UK, Professor Z. Waszczyszyn, Poland, Professor N.P. Weatherill, UK, Professor N-E Wiberg, Sweden, Professor J.P. Wolf, Switzerland, Professor W. Wunderlich, Germany, Professor Yong Bin Yang, Taiwan, and Dr. Th. Zimmermann, Switzerland.

The idea of holding the Third International Conference on Computational Structures Technology in Budapest came from János Sziveri, Heriot-Watt University, Edinburgh. I should like to thank him for his help, advice and support over the two year period before this conference. My thanks are also due to all at Civil-Comp Press for their help and perserverance in the realisation of this conference, particularly Szandra Köves and Maisie Sales. The assistance of

members of the Structural Engineering Computational Technology Research Group at Heriot-Watt University, Edinburgh is gratefully acknowledged particularly from Péter Iványi, Biao Cheng, Ardeshir Bahreininejad, Joao P.B. Leite and Janet Wilson.

Barry Topping Department of Mechanical and Chemical Engineering Heriot-Watt University, Edinburgh August 1996