DEVELOPMENTS IN CIVIL AND CONSTRUCTION ENGINEERING COMPUTING

DEVELOPMENTS IN CIVIL AND CONSTRUCTION ENGINEERING COMPUTING

Edited by B. H. V. TOPPING



CIVIL-COMP PRESS

10 Saxe-Coburg Place Edinburgh, EH3 5BR, UK

© 1993, Civil-Comp Limited

British Library Cataloguing in Publication Data

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

ISBN 0-948749-17-2

Printed in Scotland by MEIGLE PRINTERS LTD Galashiels

1 CONSTRUCTION

	1.1 1.2	LIFE CYCLE COSTING OF OFFICE BUILDINGS AT THE PRELIMINARY DESIGN STAGE, A.C. Khanduri, C. Bédard and S. Alkass, Centre for Building Studies, Concordia University, Montreal, Quebec, Canada	1		
		Alkoc, Department of Architecture, Middle East Technical University, Ankara, Turkey	9		
	1.3	A COMPUTER MODEL FOR THE ASSESSMENT OF CONSTRUCTION PRICE CHANGES UNDER HIGH INFLATION, C. Maroun and S Alkass, Centre for Building Studies, Concordia University, Montreal, Quebec, Canada	15		
2	CO 2.1	NSTRUCTION MANAGEMENT AN INTEGRATED PERFORMANCE EVALUATION SYSTEM (IPES), C. Ran- dall, P.H. McGowan and R.M.W. Horner, The Construction Management Re- search Unit, Department of Civil Engineering, University of Dundee, Dundee,			
	2.2	Scotland	25		
	2.3	ada	33		
	2.4	States of America	39 41		
3	GEOTECHNICAL ENGINEERING: ANALYSIS AND DESIGN				
	3.1	AN ALGORITHM FOR SETTLEMENT OF PILES IN STRATIFIED SOILS, C. Romanel, P. Rocha Filho and M.A. Cangussu, Department of Civil Engineering, Catholic University of Rio de Janeiro, Rio de Janeiro, Brazil	51		
	3.2	DYNAMIC FLEXIBLE MATRIX OF SOIL LAYER TO LATERALLY LOADED PILES, K. Sun [†] and J.A. Pires [‡] , [†] Department of Civil Engineering, National University of Singapore, Singapore, [‡] Department of Civil Engineering, University			
	3.3	of California, Irvine, United States of America	57		
	3.4	America	65		
	3.5	University at Carbondale, Carbondale, Illinois, United States of America, INTEGRATED COMPUTER AIDED FOUNDATION DESIGN, A. Nanda and S. Kumar, Engineers India Limited, New Delhi, India	73 79		
	3.6	ALLOWABLE BEARING CAPACITY OF SHALLOW FOUNDATIONS ON GEOGRID-REINFORCED SAND, B.M. Das, V.K. Puri, S.C. Yen, E.E. Cook	19		
		and M.A. Wright, Southern Illinois University, Carbondale, Illinois, United States of America,	89		

4	GEOTECHNICAL ENGINEERING: MODELLING AND TESTING					
	4.1	NON-ASSOCIATED ANISOTROPIC ELASTO-PLASTIC MODELS FOR CLAYS,				
		A.R. Bondok, Department of Civil Engineering, Helwan University, Cairo, Egypt 95				
	4.2	LIQUEFACTION CHARACTERISTICS OF SILTS, S. Singh, Department of				
		Civil Engineering, Santa Clara University, Santa Clara, California, United States				
		of America,				
	4.3	A COMPUTER CONTROL SYSTEM FOR STRESS PATH TRIAXIAL TEST-				
		ING, D.G. Toll, Geotechnical Systems Group, School of Engineering and Com-				
		puter Science, University of Durham, Durham, England				
		SPATIAL DISTRIBUTION OF INFILTRATION IN THE FIELD, Z. Li and L.W.				
	4.4					
		Apperley, School of Civil and Mining Engineering, University of Sydney, Sydney,				
		Australia				
5	GEOTECHNICAL ENGINEERING: ANALYSIS AND DESIGN					
ð						
	5.1	THE APPLICATION OF A SOIL STRUCTURE INTERACTION PROCEDURE				
		TO THE ANALYSIS AND DESIGN OF RAFT FOUNDATIONS, I.D. Lefast,				
		V.N. Georgiannout and D.A. Shepherdt, tEngineering and Power Development				
		Consultants Ltd, Sidcup, Kent, England, ‡Department of Civil Engineering, Im-				
		perial College of Science and Technology, London, England 123				
	5.2	PARTIALLY SATURATED CONSOLIDATION OF EMBANKMENT DAMS				
		DURING CONSTRUCTION, A. Nanda, Engineers India Limited, New Delhi,				
		India				
0	OF	OTECHNICAL ENGINEERING: FINITE ELEMENT ANALYSIS				
6						
		TEREAT OF FILLE BULLY MODILING MADIATION ON THE OPERAL				
	6.1	EFFECT OF FLUID BULK MODULUS VARIATION ON THE CRITICAL				
	6.1	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN				
	6.1	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood,				
		TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141				
	6.16.2	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU-				
		TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S.				
	6.2	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	6.2	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	6.2	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America 153 AN ABSORBING BOUNDARY CONDITION FOR WAVE PROPAGATION IN SATURATED POROELASTIC MEDIA: FINITE ELEMENT FORMULATION,				
	6.2	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	6.2	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	6.2	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	6.2 6.3	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	6.2 6.3	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
_	6.26.36.4	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
7	6.26.36.4TRA	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
7	6.26.36.4	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
7	6.26.36.4TRA	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
7	6.26.36.4TRA	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	 6.2 6.3 6.4 TRA 7.1 	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	 6.2 6.3 6.4 TR.4 7.1 WA⁶ 	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	 6.2 6.3 6.4 TRA 7.1 	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				
	 6.2 6.3 6.4 TR.4 7.1 WA⁶ 	TIME STEP FOR DYNAMIC ANALYSIS OF SATURATED SOIL USING AN EXPLICIT U-W SCHEME, A.H.C. Chan, O.O. Famiyesin and D. Muir Wood, Department of Civil Engineering, University of Glasgow, Glasgow, Scotland 141 FINITE ELEMENT ANALYSIS OF SHAFTS AND TUNNELS FOR THE SU- PERCONDUCTION SUPER COLLIDER PROJECT, Wern-ping Chen and S. Bauldauf, The PB/MK Team, Dallas, United States of America				

	8.2	OPTIMAL DESIGN OF HYDRAULIC NETWORKS FOR WATER SUPPLY, P.S.F. Barbosa and A.P. Graciano, Deparment of Civil Engineering, UNICAMP, Brazil	97
9		TERIALS ENGINEERING	
	9.1	QUALITY ASSURANCE OF CONCRETE CONSTRUCTION THROUGH THE	
		USE OF COMPUTERS, K.C. Hover, G.L. Johnson and C.W. Farrell, School of	
		Civil & Environmental Engineering, Cornell University, Ithaca, United States of	
		America	03

iv

• PREFACE •

This volume contains some of the papers presented at *CIVIL-COMP93*, The Fifth International Conference on Civil and Structural Engineering Computing and *Artificial Intelligence CIVIL-COMP93*, The Third International Conference in the Application of Artifical Intelligence to Civil and Structural Engineering. These conferences were held currently from 17th - 19th August 1993 at Heriot-Watt University, Edinburgh, Scotland. Other papers from these conferences are published in:

- Information Technology for Civil and Structural Engineers, Civil-Comp Press, (ISBN 0-948749-16-14)
- Knowledge Based Systems for Civil and Structural Engineering, Civil-Comp Press, (ISBN 0-948749-19-9)
- Developments in Structural Engineering Computing, Civil-Comp Press, (ISBN 0-948749-20-2)
- Developments in Computational Engineering Mechanics, Civil-Comp Press, (ISBN 0-948749-21-0)
- Neural Networks and Combinatorial Optimization in Civil and Structural Engineering, Civil-Comp Press, (ISBN 0-948749-18-0)

I should like to thank all the authors for their contribution and in particular those who travelled to Edinburgh to present their papers at the Conferences. I should also like to thank members of the Conference Advisory Boards for their assistance.

The members of the CIVIL-COMP93 Conference Advisory Board were: Dr T.J.A. Agar, University of Glasgow, U.K.; Dr R.J. Allwood, University of Technology, Loughborough, U.K.; Dr M.R. Barnes, The City University, London, U.K.; Dr P. Bhatt, University of Glasgow, U.K.; Dr J.W. Bull, University of Newcastle upon Tyne, U.K.; Dr H.C. Chan, University of Hong Kong, Hong Kong; Professor Chang-Koon Choi, Korea Advanced Institute of Science and Technology, South Korea; Professor J Christian, University of Brunswick, Canada; Professor B.M. Das, Southern Illinois University at Carbondale, United States of America; Professor H. Eschenauer, University of Seigen, Germany; Professor D. Frangopol, University of Colorado at Boulder, United States of America; Professor J.A. Teixeira de Freitas, Universidade Tecnica de Lisboa, Portugal; Professor D.E. Grierson, University of Waterloo, Canada; Professor G. Guerlement, Faculte Polytechnique Mons, Belgium; Professor E. Hinton, University College of Wales, Swansea, U.K.; Professor K.C. Hover, Cornell University, United States of America; Professor A. Jennings, The Queen's University of Belfast, U.K.; Professor A. Kaveh, Iran University of Science and Technology, Iran; A.I. Khan, Heriot-Watt University, Edinburgh, U.K.; Professor U. Kirsch, Technion - Israel Institute of Technology, Israel, Dr R Levy Technion - Israel Institute of Technology, Israel; Professor I.A. MacLeod, University of Strathclyde, Glasgow, U.K.; Professor I. May, Heriot-Watt University, Edinburgh, U.K.; Professor R. McCaffer, University of Technology, Loughborough, U.K.; Professor J.L. Meek, University of Quuensland, Australia; Professor R.E. Melchers, The University of Newcastle, Australia; Professor M. Papadrakakis, National Technical University of Athens, Greece; Dr F. Papp; Technical University of Budapest, Hungary; Dr M. Pavlovic, Imperial College, London, U.K.; Dr R. Powell, Brunel University, U.K.; Professor R. Richard, The University of Arizona, United States of America; Professor G. De Roeck, Katholieke Universiteit te Leuven, Belgium; Professor G. Rozvany, University of Essen, Germany; Professor R.L. Sack, University of Oklahoma, United States of America; Professor M.P. Saka, University of Bahrain, State of Bahrain; Professor A. Samartin, Mechanica de los Medios Continuos, Spain; Professor N. Shiraishi, Kyoto University, Japan; Professor L.M.C. Simoes, University of Coimbra, Portugal; Dr G. Singh, University of Leeds, U.K.; Dr T.D. Sloan,

The Queen's University of Belfast, U.K.; Dr D. Lloyd Smith, Imperial College, London, U.K.; Gordon Smyrell, University of Teesside, U.K.; Professor W.R. Spillers, New Jersey Institute of Technology, United States of America; Professor R.M. Stark, University of Delaware, United States of America; Professor H. Sugimoto, Muroran Institute of Technology, Japan; David Taffs, Ove Arup & Partners, London, U.K.; Professor A.B. Templeman, University of Liverpool, U.K.; Professor G. Thierauf, University of Essen, Germany; Dr D.G. Toll, University of Durham, U.K.; Professor N.S. Trahair, The University of Sydney, Australia; Dr G.J. Turvey, University of Lancaster, U.K.; Professor K.S. Virdi, The City University, London, U.K.; Dr S. Walker, National Rivers Authority, Warrington, U.K.; Dr A. Watson, Leeds University, U.K.; Dr F.L. Wong, University of Hertfordshire, U.K.; and Professor Yong Bin Yang, National Taiwan University Taipei, Taiwan.

The members of the Artificial Intelligence CIVIL-COMP93 Advisory Board were: Dr M. Alshawi, University of Salford, U.K.; Professor T. Arciszewski, Wayne State University, United States of America; Dr E Balagurusamy, National Centre for Expert Systems, India; Dr R Beheshti, Delft University of Technology, The Netherlands; Professor D.I. Blockley, University of Bristol, U.K.; Dr D.A. Bradley, University of Lancaster, U.K.; Dr C. Burgoyne, University of Cambridge, U.K.; D. Chamberlain, The City University, U.K.; W.T. Chan, National University of Singapore; Dr T. Cornick, University of Reading, U.K.; Dr R. Coyne, The University of Sydney, Australia; Dr I.E.G. Davey-Wilson, Oxford Polytechnic, U.K.; Dr C.L. Dym, University of Massachusetts, United States of America; E.W. East, US Army Construction Engineering Research Laboratory, United States of America; Professor S.J. Fenves, Carnegie-Mellon University, United States of America; Dr M.A. Fischer, Stanford University, United States of America; Dr R. Fruchter, Stanford University, United States of America; Dr H. Furuta, Kyoto University, Japan; Professor J.M. De La Garza, Virginia Polytechnic Institute and State University, United States of America; Professor J.S. Gero, The University of Sydney, Australia; Professor F.C. Hadipriono, Ohio State University, United States of America; Professor P. Hajela, Rensselaer Polytechnic Institute, United States of America; Dr B.G. Heydecker, University College, London, U.K.; K. Kahkonen, Technical Research Centre of Finland, Espoo, Finland; A.I. Khan, Heriot-Watt University, Edinburgh, U.K.; Dr B. Knight, The University of Greenwich, London, U.K.; Dr V.K. Koumousis, National Technical University of Athens, Greece; Professor C.S. Krishnamoorthy, Indian Institute of Technology - Madras, India; Dr B. Kumar, University of Strathclyde, Glasgow, U.K.; J. Lansdown, Middlesex Polytechnic, U.K.; Professor K.H. Law, Stanford University, United States of America; Professor K.L. Lawrence, The University of Texas at Arlington, United States of America; Professor Liu Xihui, China Academy of Electronics & Information Technology, Beijing, P R China; Professor I.A. MacLeod, University of Strathclyde, Glasgow, U.K.; Professor M.L. Maher, University of Sydney, Australia; Dr J. Miles, University of Wales, Cardiff, U.K.; Dr S.G. Ritchie, University of California, Irvine, United States of America; Dr S. Rowlinson, Hong Kong University; Dr G.G. Roy, The University of Western Australia, Australia; Dr H.C. Shah, Stanford University, United States of America; Dr C.-K. Soh, Nanyang Technological Institute, Singapore; Dr W.J. Spencer, Swimburne Institute of Technology, Australia; Professor D. Sriram, Massachusetts Institute of Technology, Cambridge, United States of America; Professor G. Yagawa, University of Tokyo, Japan; and Dr K. Zreik, Association EuropIA, Paris, France.

Finally, I should like to thank the other members of the Heriot-Watt University's Structural Engineering Computational Technology Research Group in particular: Asad Khan, János Sziveri, Jørgen Stang, Ardeshir Bahreininejad, João P. de Barros Leite and Janet Wilson.

> B.H.V. Topping Heriot-Watt University Edinburgh