Finite Elements in Engineering & Science

PROCEEDINGS OF THE SECOND INTERNATIONAL DIANA CONFERENCE
COMPUTATIONAL MECHANICS '97
AMSTERDAM/NETHERLANDS/4-6 JUNE 1997

Finite Elements in Engineering and Science

Edited by
MAX A. N. HENDRIKS
TNO Building and Construction Research, Delft, Netherlands
HANS JONGEDIJK
DIANA Users Association, Arnhem, Netherlands
JAN G. ROTS
DIANA Foundation & Delft University of Technology, Netherlands
WILLEM J. E. VAN SPANJE
DIANA Analysis bv, Delft, Netherlands

A.A. BALKEMA/ROTTERDAM/BROOKFIELD/1997

Centre for Civil Engineering
Research and Codes

Centre for Underground
Construction

DIANA Analysis bv

DIANA Users Association

Ministry of Transport,
Public Works and
Water Management

ING BANK

TNO Building and
Construction Research

Delft University of Technology
Faculty of Civil Engineering

Netherlands School
For Advanced Studies
In Construction

Technology Foundation

The texts of the various papers in this volume were set individually by typists under the supervision of each of the authors concerned.

Published by
A.A. Balkema, P.O. Box 1675, 3000 BR Rotterdam, Netherlands (Fax: +31.10.4135947)
A.A. Balkema Publishers, Old Post Road, Brookfield, VT 05036-9704, USA
(Fax: 802.2763837)

ISBN 90 5410 883 5

Printed in the Netherlands

FINITE ELEMENTS IN ENGINEERING AND SCIENCE

Finite Elements in Engineering and Science, Hendriks, Jongedijk, Rots & van Spanje (eds)
© 1997 Balkema, Rotterdam, ISBN 90 5410 883 5

Preface

In 1972 TNO Building and Construction Research originated the development of the DIANA finite element code. Initially, the idea was to develop an in-house code for research and consultancy. Gradually, the attractiveness of the code was also recognized by engineering offices and researchers outside TNO. For this reason, professional executable product versions of DIANA were prepared and made available to external users since 1980. The first users came from the Netherlands, but soon the commercialisation was undertaken world-wide with emphasis on Europe, Japan and Korea. The research community discovered DIANA's potential as a software development environment in addition to its service for end-use and asked for access to the source code and programmer's toolkit to undertake developments. This led to a multi-disciplinary effort and a continuous process of renewal, partially supported by the Ministry of Transport, Public Works and Water Management, CUR, NWO/STW and others.

Now, 1997, twenty five years later, DIANA has gained a strong position in Computational Mechanics, still characterized by two key-words: research and end-use. It is the purpose of this Second International DIANA Conference on Computational Mechanics to bring together researchers and end-users engaged in finite element modelling. In line with the first conference, held in 1994 in Delft, the conference is of special interest to those involved in new developments in computational mechanics as well as those who are interested in its wide variety of applications.

The papers and sessions are grouped under the following headings:

- Concrete mechanics and concrete structures;
- Geomechanics and soil-structure interaction;
- Steel and composite structures;
- Computational mechanics of materials;
- Finite element technology and software development.

For each session, practical and theoretical contributions have been mixed, so as to encourage lively discussions and to promote utilisation driven research as well as research driven utilisation.

In line with the first conference in 1994, the second conference is jointly organized

by the four parties that form the DIANA knowledge chain (see also internet http://www.diana.nl):

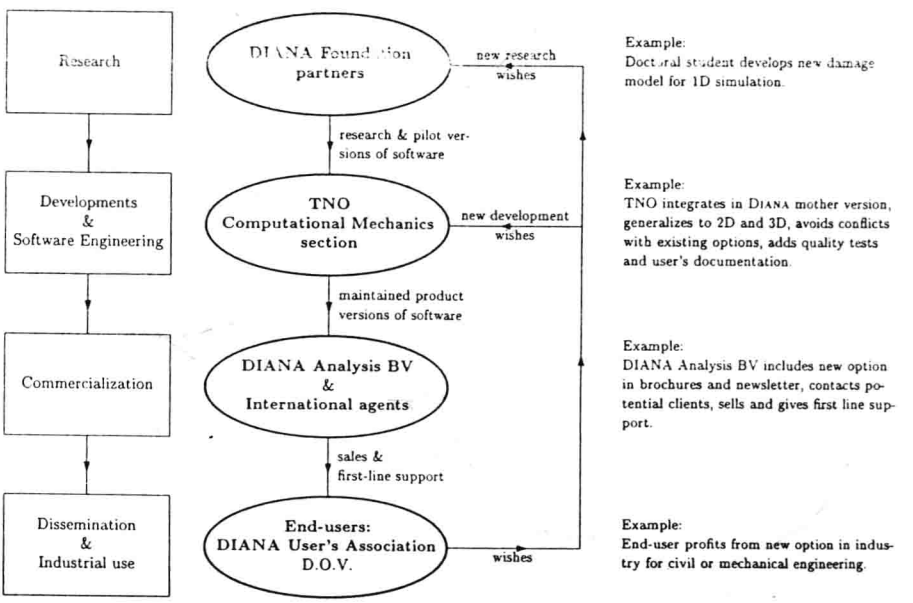
– DIANA Foundation. The DIANA Foundation is a joint initiative of universities, research institutes and industrial partners that undertake research with the source code of DIANA. The Foundation has been recognized by the Netherlands Organization for Scientific Research (NWO) as Expertise Centre for Computational Mechanics. Key-words are research and creation of new knowledge and pilot versions.

– TNO. TNO carries out the tasks of maintenance, integration and preparation of new product versions. Activities include software engineering, quality assurance, documentation, user interfacing, porting, data structuring, tactical developments, strategic developments, etc. The work falls under the general TNO mission 'Making technology work' and aims at bridging the gap between university type research and industry.

– DIANA Analysis BV and international agents. TNO has contracted DIANA Analysis BV and international agents to carry out tasks for commercialisation. At present, agents are active in Japan, Korea, UK, Portugal and Spain and Poland, while DIANA Analysis BV is head office and serving the other regions of the world. Key words are marketing, sales, distribution and first-line user's support.

– DIANA User's Association (DOV). End-users of DIANA are present in research, industry and engineering offices. The Netherlands users have organized themselves into the DIANA User's Association. The users provide feed-back to the developers by formulating wishes for new developments and new research.

DIANA Knowledge Flow



The four organizing parties hope that this volume and the conference sessions contribute to strengthening the relationships and to intensifying the knowledge flow illustrated above.

The timing of the conference is such that it provides a unique opportunity to celebrate the 25th anniversary of DIANA with colleagues and friends from the computational modelling circle. There will be time for retrospective and even nostalgic views over the past 25 years, for characterizing the present situation and for announcing the future policy of DIANA Foundation and TNO. This will cover technical, commercial as well as policy aspects, with anticipation on new trends not only in computational mechanics, algorithms and constitutive modelling, but also on developments in the field of graphical user interfaces and specials (vertical applications, dedicated software for design and analysis), developments in the data structuring and building block philosophy of DIANA, and trends in adaptation to new hardware and software standards.

I wish the participants the best success and much satisfaction in the conference.

Johan Blaauwendraad
Conference Chairman
Delft University of Technology
March, 1997

Finite Elements in Engineering and Science, Hendriks, Jongedijk, Rots & van Spanje (eds)

Acknowledgements

As organizers of the Second International DIANA Conference on Finite Elements in Engineering and Science, we wish to express our cordial thanks to the keynote speakers and all colleagues that accepted the invitation to present their work at this Second International DIANA Conference and to prepare their high-quality papers for inclusion in these proceedings.

We also sincerely thank the members of the Technical Advisory Panel for their support in reviewing the abstracts and papers, and Professor Johan Blaauwendraad, chairman of the DIANA Foundation and Dean of Delft University of Technology, for his willingness to act as conference chairman.

We would like to thank Mireille Wingelaar from DIANA Analysis BV for her important contribution and secretarial assistance in organizing this conference.

The financial support from the following sponsors is gratefully acknowledged:

- Ministry of Transport, Public Works and Water Management;
- Netherlands Technology Foundation (STW);
- Centre for Civil Engineering Research and Codes (CUR);
- Centre for Underground Structures (COB);
- Delft University of Technology, Faculty of Civil Engineering;
- Netherlands School for Advanced Studies in Construction;
- ING Bank;
- DIANA Foundation;
- TNO Building and Construction Research;
- DIANA Analysis BV;
- DIANA User's Association (DOV).

We hope that the conference helps to identify the proper balance between research and utilisation in computational modelling with DIANA. We hope that the readers of this volume will find a state-of-the-art in various areas in computational mechanics, its theory and its applications.

Delft, March 1997

Max A.N. Hendriks, TNO Building and Construction Research
Hans Jongedijk, DIANA User's Association
Jan G. Rots, DIANA Foundation/Delft University of Technology
Willem J.E.van Spanje, DIANA Analysis BV

Finite Elements in Engineering and Science, Hendriks, Jongedijk, Rots & van Spanje (eds)
© 1997 Balkema, Rotterdam, ISBN 90 5410 883 5

Organization

Technical Advisory Panel

R.Al-Mahaidi, Clayton, Australia
K.J.Bakker, Utrecht, Netherlands
J.Blaauwendraad, Delft, Netherlands
A.de Boer, Utrecht, Netherlands
R.de Borst, Delft, Netherlands
D.H.van Campen, Eindhoven, Netherlands
A.Carpinteri, Torino, Italy
R.Danesi, Tucumán, Argentina
L.Elfgren, Luleå, Sweden
R.Eligehausen, Stuttgart, Germany
L.J.Ernst, Delft, Netherlands
B.Espion, Brussels, Belgium
J.A.Figueiras, Porto, Portugal
H.Horii, Tokyo, Japan
J.M.R.J.Huyghe, Maastricht, Netherlands
A.R.Ingraffea, Ithaca, USA
M.Laasonen, Tampere, Finland
C.Meyer, New York, USA
J.G.M.van Mier, Delft, Netherlands
H.Mihashi, Sendai, Japan
A.Mutoh, Nagoya, Japan
M.Prat, Bagneux, France
Ha-Won Song, Seoul, Korea
S.I.Sørenson, Trondheim, Norway
N.Spidsøe, Trondheim, Norway
J.W.B.Stark, Delft, Netherlands
L.Taerwe, Ghent, Belgium
V.Toropov, Bradford, United Kingdom
A.Verruijt, Delft, Netherlands
J.C.Walraven, Delft, Netherlands
Z.Waszczyszyn, Cracow, Poland
F.H.Wittmann, Zürich, Switzerland

Finite Elements in Engineering and Science, Hendriks, Jongedijk, Rots & van Spanje (eds)
© 1997 Balkema, Rotterdam, ISBN 90 5410 883 5

Table of contents

Geomechanics and soil-structure interaction

Steel and composite structures

Computational mechanics of materials

Finite element technology and software development

Concrete mechanics and concrete structures

Finite Elements in Engineering and Science, Hendriks, Jongedijk, Rots & van Spanje (eds)
© 1997 Balkema, Rotterdam, ISBN 90 5410 883 5

Invited paper: Effect of nonlinear behaviour of structures under earthquake action

Th. Baumann & J. Böhler
DYWIDAG, Structural Design Department, Munich, Germany

Abstract

In many cases the maximum dynamic response of a nonlinear structure is evaluated using so-called inelastic design spectra. These inelastic spectra are gained dividing the elastic spectra by behaviour factors, which consider the effect of plastic deformations enabled by the ductility of the structure. The present paper reports about comparisons of nonlinear time-history analyses with the application of behaviour factors and inelastic response spectra, respectively. The investigation of typical structures and earthquakes shows the approach by means of inelastic spectra to be very rough. If more reliable informations about forces and displacements of nonlinear structures are required, they have to be obtained by carrying out time-history analyses under consideration of the nonlinear behaviour of the structure.

1 Introduction

Common standards like UBC '94 [9], EC 8 [3], API 620 [1] etc. allow to consider the effects of the nonlinear behaviour of a structure, dividing its elastic response - assuming it remains elastically beyond the real yield limit - by a factor which is in a range between 4.0 and 12.0, depending on the statical system and the material. Sometimes not the elastic response of a structure is reduced, but in advance the spectrum, i.e. the loading, itself, however, leading to same results (inelastic design spectrum). The reason, why this approach is permitted, may be the object to avoid a nonlinear dynamic time-history analysis requiring much more time and money than a response spectrum analysis, which is strictly limited to linear systems. An early substantiation of response and design spectra for inelastic systems has been given by Blume/Newmark/Corning [2]. In [5], [6] formulas have been proposed for the determination of an appropriate reduction factor (= behaviour factor), presupposing a given ductility. The question, in how far the effect of nonlinearities can be considered by means of simple reduction of the elastic results, is discussed following by investigation of an uplifting steel tank, which has been treated as a typical nonlinear 1DOF-system with *DIANA*.