

*Recent Advances in Matrix Methods
of Structural Analysis and Design*

edited by

R. H. Gallagher, Y. Yamada, J. Tinsley Oden

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Papers presented at the U. S.-Japan
Seminar held at Tokyo in August 1969
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Foreword

During the period since the U. S. - Japan Cooperative Science Program was formally initiated in 1961, there have been more than three hundred joint seminars and cooperative research projects involving the participation of several thousand American and Japanese scientists. These scientific meetings and research projects have no doubt made a great contribution to the promotion of science, to scientific cooperation and to the dissemination of information among scientists of the two countries as well as among scientists of other lands.

The U. S. National Science Foundation and the Japan Society for the Promotion of Science are the implementing agencies for the U. S. - Japan Cooperative Science Program. They work closely together to support American and Japanese scientists in organizing seminars, in conducting cooperative research, and in providing other opportunities for joint scientific activities.

As stated in the messages of President Johnson and Prime Minister Sato to the sixth meeting of the U. S. - Japan Committee on Scientific Cooperation held in 1966: "This has been a truly joint program ... it is highly gratifying to note the progress that has been made by the dedicated scientists of both countries in this area of joint effort ..." and "... express the hope that this work will continue to promote the cause of peace and welfare for all mankind."

The excellent; and, scientific papers presented at seminars or produced as a result of a cooperative research effort have often appeared later in scientific periodicals; and, in some cases, all the collected papers of a given seminar have even been published in book form. It has been our great pleasure to read again the excellent papers presented at the Seminar on Matrix Methods of Structural Analysis and Design in this book, which we believe will be of great interest to all scientists concerned and particularly useful for younger scientists in this field.

We wish to extend our thanks and grateful appreciation to all who helped make this Seminar an outstanding event. In particular, we would

like to extend special thanks to Dr. Richard H. Gallagher, Professor of Cornell University, and to Drs. Tadahiko Kawai and Yoshiaki Yamada, Professors of Tokyo University. Without their strenuous efforts and the sacrifice of their precious time for the organization of the Seminar it would have been difficult to have obtained these very fruitful results.

J. E. O'Connell
Program Director, U. S. - Japan
Cooperative Science Program
National Science Foundation

Masao Yoshiki
Chief Director
Japan Society for the Promotion
of Science

Main Organizer of the Seminar on
Matrix Methods of Structural
Analysis and Design

Preface

The papers presented in this volume result from an unusual form of international cooperation, the bi-national meeting. In such an arrangement, an attempt is made to acquaint each national group with the background of a specific field in the other country and with the progress of research in this field. The field of the present seminar, however, is potentially so broad that a number of more specific decisions on subject matter were necessary in fashioning a program. Since these factors determined the contents of this Proceedings volume, it is useful to describe at the outset the development and planning of the Seminar program.

It is well recognized that new and powerful concepts in all aspects of structural analysis and design have emerged in recent years. These concepts, which are motivated by and pertain to the special characteristics of the computer, can be grouped under the general term "matrix structural analysis" and often feature the utilization of the methodology known as the "finite element procedure".

Significant developments in matrix methods of structural analysis and design, based upon finite element concepts, took place in the U. S. and Europe during the decade 1952 — 62, mainly in connection with the design of aerospace vehicles. Since the early 1960's, however, the fields of application have expanded steadily from aerospace to civil, mechanical, shipbuilding, and virtually all forms of engineering that involve structural design. These methods form the basis for the routine analysis of many structures in both large and small design offices.

In Japan, where pioneering isolated developments were accomplished in this area over a long period of time, extensive research activities have only been initiated since approximately 1965. Yet, the growth of interest in matrix analysis and design methods in Japanese academic institutions and industrial organizations has been amazingly rapid. The development of all aspects of this new field advanced with undiminished vigor on a nationwide scale, and a considerable amount of significant

work had already been accomplished by 1967.

The Japanese research work was mainly concerned with basic theoretical studies; developmental activities related to large-scale computing systems and general purpose computing programs had just begun. Consequently, it became apparent during 1967 that an awareness and understanding of U. S. achievements in those aspects of the field would accelerate greatly the application to practical engineering problems in Japan; in turn, the results of Japanese research would benefit U. S. theorists. With the above factors in mind, planning for a U. S. - Japan Seminar in Matrix Methods of Structural Analysis and Design was initiated in late 1967.

Joint sponsorship of the proposed Seminar was obtained from the U. S. National Science Foundation (NSF) and the Japan Society for the Promotion of Science (JSPS). In accordance with the rules for seminars under NSF/JSPS sponsorship, participation was limited to twenty individuals for the United States and a somewhat larger Japanese delegation. Steering committees were established in each country and from these emerged the details of locale, scope of the Seminar, and participation. Plans were finalized in the Spring of 1969.

The U. S. - Japan Seminar on Matrix Methods of Structural Analysis and Design was formally convened in Tokyo on Monday, August 25, 1969, in the Conference room of the Nohkyo Building, Tokyo. An intensive program of survey and technical papers, detailed below, was presented during five days of sessions. Sessions were devoted to General Theory, Material and Geometric Nonlinearities, Dynamics, Optimum Design, Applications in Practice, and Special Problems. In general, each session was initiated by presentations of papers which surveyed the state-of-the-art in a given field in the United States and Japan, respectively. These were followed by papers describing individual research programs or descriptions of practical applications.

In order to achieve a well rounded program, certain papers which had been delivered or published elsewhere were invited for presentation at the Seminar. In addition, provision was made in the Seminar program for Japanese papers describing research in progress or of more specialized interest. Both types of papers have been omitted from these Proceedings. Publication data for the papers in the former category is cited below in connection with the Seminar program. It is anticipated that many of the papers in the second category will be contributed to the open literature in the near future.

The Editors would like to take this opportunity to express their sincere thanks to the many individuals who contributed to the success of the program. They are especially appreciative of the efforts of Prof. Yoshiki of JSPS and Dr. J. E. O'Connell of NSF, whose advice and encouragement brought the seminar to fruition. The Japan Society for Steel Construction, through the offices of Prof. Naka, is owed a debt

of gratitude for its sponsorship of many aspects of the seminar. The respective Japanese and U. S. steering committees deserve commendation for developing the planning of the program, and special thanks is due Prof. Tadahiko Kawai, who worked tirelessly from the inception of the Seminar idea to the meeting itself in the accomplishment of both the program and in affording the incomparable Japanese hospitality to the U. S. delegates.

R. H. Gallagher

Y. Yamada

J. T. Oden

Technical Program

SESSIONS ON BASIC THEORY

(Monday, Aug. 25)

MORNING SESSION

CHAIRMEN:

R. H. Gallagher

Y. Tsuboi

Survey Paper
(U.S.)

*Formulations of Finite Element Methods
for Solid Continua* (T.H.H. Pian)

Survey Paper
(Japan)

*Some Remarks on Basic Theory for
Finite Element Method* (K. Washizu)

Technical Paper
(Japan)

*Analysis of Saint-Venant Torsion
Problem by a Hybrid Stress Method**
(Y. Yamada, S. Nakagiri, and
K. Takatsuka)

Technical Paper
(Japan)

*Finite Element Approaches with the Aid
of Analytical Solutions* (Y. Yamamoto,
S. Nakagiri, and K. Takatsuka)

AFTERNOON SESSION

Survey Paper
(Japan)

*New Approaches to Finite Element
Method* (J. Suhara and J. Fukuda)

Survey Paper
(Japan)

*Finite Element Analysis of Shell
Structures in Japan*[†] (T. Kawai)

Technical Paper
(U.S.)

*A Mixed Finite Element Shell Formula-
tion* (J. Connor and G. T. Will)

Technical Paper
(Japan)

*Discrete Triangular Approximation of
Moment and Displacement Surfaces for
Plate Bending Analysis* (Y. Yoshida)

**Seisan-Kenkyu* (Monthly Journal of Institute of Industrial Science)
Vol. 21, No. 11, 1969.

[†] *Seisan-Kenkyu* (Monthly Journal of Japanese Institute of Industrial
Science) Vol. 22, No. 1, 1970.

Technical Paper
(U.S.)

Some New Developments in Matrix Force Analysis (J. Robinson and G. Haggemacher)

SESSIONS ON NONLINEAR PROBLEMS
(Tuesday, Aug. 26)

MORNING SESSION

Material Nonlinearity

CHAIRMAN:

J. T. Oden

Survey Paper
(U.S.)

Finite Element Analysis with Material Nonlinearities - Theory and Practice
(P. V. Marcal)

Survey Paper
(Japan)

Recent Japanese Developments in Matrix Displacement Method for Elastic-Plastic Problems in Japan (Y. Yamada)

Survey Paper
(Japan)

*Elastic-Plastic Matrix Analyses of Foundation and Reinforced Concrete in Japan** (H. Yamaguchi)

Technical Paper
(Japan)

Analysis of Stress and Strain Distribution at Crack Tip by the Finite Element Method (H. Miyamoto, M. Shiratori, and T. Miyoshi)

Technical Paper
(Japan)

*On the States of Stress and Deformation of Cylindrical Specimens of Brittle Material Under Uniaxial Compression**
(T. Kawamoto and T. Kajita)

AFTERNOON SESSION

Geometric and Combined Nonlinearity

CHAIRMAN:

H. Miyamoto

Survey Paper
(U.S.)

Finite Element Formulation of Geometrically Nonlinear Problems
(H. C. Martin)

Technical Paper
(U.S.)

Finite Element Formulation of Geometrically Nonlinear Problems of Elasticity (B. J. Hartz and J. D. Nathan)

Technical Paper (Japan)	<i>Finite Element Analysis of the Geometrically Nonlinear Problems</i> (T. Kawai)
Technical Paper (Japan)	<i>Analysis of Elastic-Plastic Buckling of Plates by Finite Element Method*</i> (Y. Ueda)

SESSIONS ON DYNAMICS
(Wednesday, Aug. 27)

MORNING SESSION

CHAIRMEN:	M. J. Turner Y. Yamamoto
Survey Paper (Japan)	<i>Dynamic Analysis on Civil Engineering Structures</i> (Y. Yamada)
Survey Paper (U.S.)	<i>Analysis of Structural Vibrations and Dynamic Response</i> (R. Clough)
Survey Paper (Japan)	<i>Dynamic Analysis of Mechanical Structures</i> (H. Shibata)
Technical Paper (Japan)	<i>Seismic Response Analysis of Buildings by the Matrix Method[†]</i> (K. Muto)

AFTERNOON SESSION

Technical Paper (U.S.)	<i>A Static and Dynamic Finite Element Shell Analysis with Experimental Verification**</i> (S. Klein)
Technical Paper (Japan)	<i>A Numerical Calculation by Finite Difference Method for Free Vibration Problems of Axisymmetric Shells^{††}</i> (M. Hamada and K. Miyata)

*Preprint No. 845, ASCE Annual Meeting, New Orleans, Louisiana, February 3-7, 1969.

[†]Published only as a seminar preprint.

**Published in the *International Journal for Numerical Methods in Engineering*, Vol. 2, No. 4, October-December 1970.

^{††}Forthcoming in *Bulletin of Japan Society of Mechanical Engineering*.

Technical Paper
(U.S.) *A Two-Dimensional Axisymmetric Shell-Fluid Model for Launch Vehicle Longitudinal Dynamic Analysis* (J. Archer, L. D. Pinson, and C. P. Rubin)

Technical Paper
(Japan) *Some Considerations of Methods for Flutter Analysis** (T. Ichikawa)

(Friday, Aug. 29)

MORNING SESSION Structural Optimization and Computer-aided Design

CHAIRMAN: R. Fulton

Survey Paper
(U.S.) *Structural Synthesis: 1959-1969, A Decade of Progress* (L. A. Schmit, Jr.)

Survey Paper
(Japan) *Optimum Design of Framed Structures** (H. Tanaka)

Survey Paper
(Japan) *Elastic-Plastic Analysis of Framed Structures* (T. Nakamura)

Technical Paper[†]
(Japan) *An Approach to the Optimum Design of Multi-Story Buildings for Earthquake Motions*[†] (B. Kato, Y. Nakamura, and H. Anraku)

Technical Paper
(Japan) *Application of Computer Graphics to Structural Analysis** (H. Togawa)

AFTERNOON SESSION Practical Applications and Numerical Analysis

CHAIRMAN: I. Konishi

Technical Paper
(U.S.) *Manipulation Error Constraints on Multicomponent Simulation of Structures* (R. J. Melosh)

*Technical Memorandum of Japanese National Aerospace Laboratory, NAL TM-151, 1968.

[†]Forthcoming in *Journal of the Structural Division*, Proc., ASCE.

**Technical Report of Japanese Aerospace Laboratory.

Technical Paper (Japan)	<i>A Method of Solving Eigenvalue Problems</i> [†] (K. Osaka)
Technical Paper (U.S.) ††	<i>A Survey of Modern Nonsense as Applied to Matrix Computations</i> * (R. Rosanoff)
Technical Paper (Japan)	<i>Numerical Analysis of Ship's Structural Elements by Means of Finite Element Method</i> [†] (M. Higuchi)
Technical Paper (U.S.)	<i>Application of Finite Element Method to Practical Ship Structure Analysis</i> [†] (J. Paulling)

(Saturday, Aug. 30)

MORNING SESSION	Numerical Analysis (II)
CHAIRMAN:	P. H. Denke
Technical Paper (Japan)	<i>Some Demands and Solutions for Practical Structural Analysis</i> [†] (M. Hattori)
Technical Paper (U.S.)	<i>ASKA—A Large Scale Software System for Finite Element Analysis</i> [†] (H. Bergmann)
Technical Paper (Japan)	<i>A Study on Composite Structures Employing Different Types of Finite Elements</i> [†] (T. Sakurai)
Technical Paper (Japan)	<i>Stress Analysis for Under-Constructing Structures</i> [†] (Y. Ohchi)
Technical Paper (Japan)	<i>Application of Finite Element Method to the Analysis of Aircraft Wing Structures</i> ^{††} (S. Sambongi)

[†] Published only as a seminar preprint.

*Published in *Proceedings of AIAA Structural Dynamics and Aeroelasticity Specialty Conference*, New Orleans, Louisiana, April 1969.

**Technical Report of Japanese National Aerospace Laboratory, NAL TR-165, 1968.

Technical Paper (Japan)	<i>Matrix Analysis of Composite Structures of Plane and Line Elements</i> (Y. Tsuboi, S. Kawamata, and S. Shioya)
AFTERNOON SESSION	Advanced Application
CHAIRMAN:	J. Suhara
Survey Paper (U.S.)	<i>Finite Element Formulation of Problems of Finite Deformation and Irreversible Thermodynamics of Nonlinear Continua</i> (J. T. Oden)
Technical Paper (Japan)	<i>Unsteady Viscous Flow Around a Cylinder Oscillating in Uniform Flow</i> (A. Okajima)
Technical Paper (U.S.)	<i>Finite Element Method for Biological Structure Analysis</i> (A. Kobayashi and S. Woo)
Technical Paper (U.S.)	<i>Finite Element Method in Fluid Flow Analysis</i> (Pin Tong)
Technical Paper (Japan)	<i>Analysis of Hydrodynamic Problems by the Finite Element Method</i> (T. Fujino)

Directory of Contributors

Anraku, Hidetake; Graduate Student

Faculty of Engineering, University of Tokyo
3-1, Hongo 7 chome, Bunkyo-ku
Tokyo 113, Japan
(Coauthor with Yuji Nakamura)

Archer, Dr. J. S.; Assistant Manager, Engineering Design Laboratory

TRW Systems
One Space Park
Redondo Beach, California 90278, U.S.A.

Bergmann, Dr. H.

North American-Rockwell Corporation
Thousand Oaks, California

Clough, R.; Professor of Civil Engineering

Department of Civil Engineering
University of California
Berkeley, California 94720, U.S.A.

Connor, J.; Professor of Civil Engineering

Department of Civil Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139, U.S.A.

Fujino, Tsutomu; Assistant Chief Engineer

Technical Administration Department
Technical Headquarters
Mitsubishi Heavy Industries, Ltd.
5-1, Marunouchi 2 chome, Chiyoda-ku
Tokyo 100, Japan

Fukuda, Jyunko; Research Assistant

Faculty of Engineering
Kyushu University
Hakozaki-cho
Fukuoka 812, Japan
(Coauthor with Jiro Suhara)

Gallagher, R. H.; Professor of Structural Engineering

Department of Structural Engineering
Cornell University
Ithaca, New York 14850, U.S.A.

Haggenmacher, Dr. G.;

Lockheed California Company
Burbank, California 91502, U.S.A.
(Coauthor with Dr. John Robinson)

Hamada, Minoru; Professor of Mechanical Engineering

Faculty of Engineering
Osaka University
Yamada-gami, Suita
Osaka 565, Japan

Hartz, B. J.; Professor of Civil Engineering

Department of Civil Engineering
University of Washington
Seattle, Washington 98105, U.S.A.

Hattori, Dr. M.; Director

Kozo Keikaku Engineering, Incorporated
Nihon Holstein Kaikan
38-13, Honcho 4 chome, Nakano-ku
Tokyo 164, Japan

Higuchi, Dr. M.; Assistant General Manager

Technical Research Center
Nippon Kokan Kabushiki Kaisha
2-1, Suehirocho, Tsurumi-ku,
Yokohama 230, Japan

Ichikawa, T.; Senior Research Engineer

First Airframe Division
National Aerospace Laboratory
1880 Jindaiji-machi, Chofu
Tokyo 182, Japan

Kajita, T.; Graduate Student

Faculty of Engineering
Nagoya University
Furo-cho, Chikusa-ku
Nagoya 464, Japan
(Coauthor with T. Kawamoto)

Kato, B.; Professor of Architecture

Faculty of Engineering
University of Tokyo
3-1, Hongo 7 chome, Bunkyo-ku
Tokyo 113, Japan
(Coauthor with Y. Nakamura)

Kawai, Tadahiko; Associate Professor, Naval Architecture
Institute of Industrial Science
University of Tokyo
22-1, Roppongi 7 chome, Minato-ku
Tokyo 106, Japan

Kawamata, Shigeya; Associate Professor, Structural Engineering
Institute of Industrial Science
University of Tokyo
22-1, Roppongi 7 chome, Minato-ku
Tokyo 106, Japan

Kawamoto, Toshikazu; Professor of Civil Engineering
Faculty of Engineering, Nagoya University
Furo-cho, Chikusa-ku
Nagoya 464, Japan

Klein, Stanley;
Aerospace Corporation
1111 E. Mill Street
San Bernardino, California 92402, U.S.A.

Marcal, P. V.; Professor of Engineering
Division of Engineering
Brown University
Providence, Rhode Island, U.S.A.

Martin, H. C.; Professor of Aeronautics and Astronautics
Department of Aeronautics and Astronautics
University of Washington
Seattle, Washington, U.S.A.

Matsuishi, Masakatsu; Research Engineer
Technical Research Laboratory
Hitachi Zosen, Ltd.
60, Sakurajima Kitano-cho, Konohana-ku
Osaka 554, Japan
(Coauthor with Yukio Ueda)

Melosh, Dr. Robert J.; Section Manager
Philco-Ford, Western Development Laboratories
Palo Alto, California 94303, U.S.A.