

STRUCTURAL STABILITY RESEARCH COUNCIL

Established in 1944 by Engineering Foundation

Proceedings
1982

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The Council has its Headquarters at:
Fritz Engineering Laboratory
Lehigh University
Bethlehem, Pennsylvania 18015

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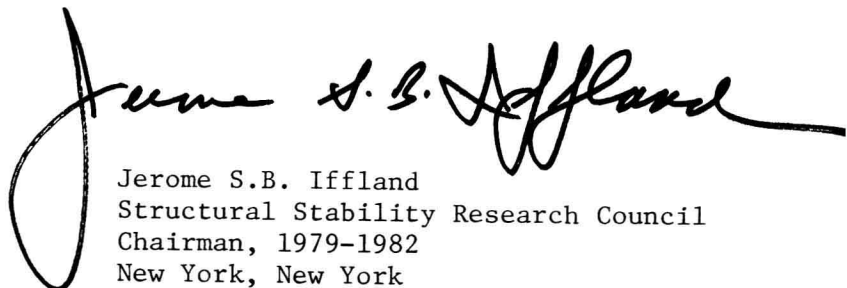
Foreword

By the time the 1982 Proceedings are published, the Fourth Edition of the "Guide" should be well underway with the first and second drafts of most chapters in the hands of Ted Galambos, who has taken over the difficult task of Editor for this volume. This is, of course, a major effort of the Council and each of you who have contributed to this new Edition, and who will continue to do so, deserve special thanks from the Executive Committee. As Chairman of the Council for the past four years, it is my privilege to thank each and every one of you for your dedication and hard work.

This coming year will also see SSRC participation in the 3rd International Colloquium on Stability. This Colloquium, being held in the four areas of the World that joined in the preparation of "Stability of Metal Structures: A World View", will follow this report with a report of new developments and a comparison of variations in the basis for design practices in different global areas. The 3rd International Colloquium will be held in Romania, France, Canada and Hong Kong with our Council planning and conducting the Session in North America. Preparation for this Session is being done by our Program Committee under the Chairmanship of Samuel Errera. This group also deserves our special thanks. With 11 Sessions and with invited theme speakers and reporters for each Session, the work effort for planning this Conference merits special commendation.

I also welcome representatives of our new participating firms, organizations and sponsors of our Council. Your participation as well as those who have stood by us in the past, provide the financial support that generates the volunteer involvement of our membership. The Financial Committee is now preparing a brochure that will document your contributions as well as the results of Council work which is SSRC's contribution to the field of Stability. Be sure to review this brochure when it becomes available. It is intended to substantiate your continued support of Council activities.

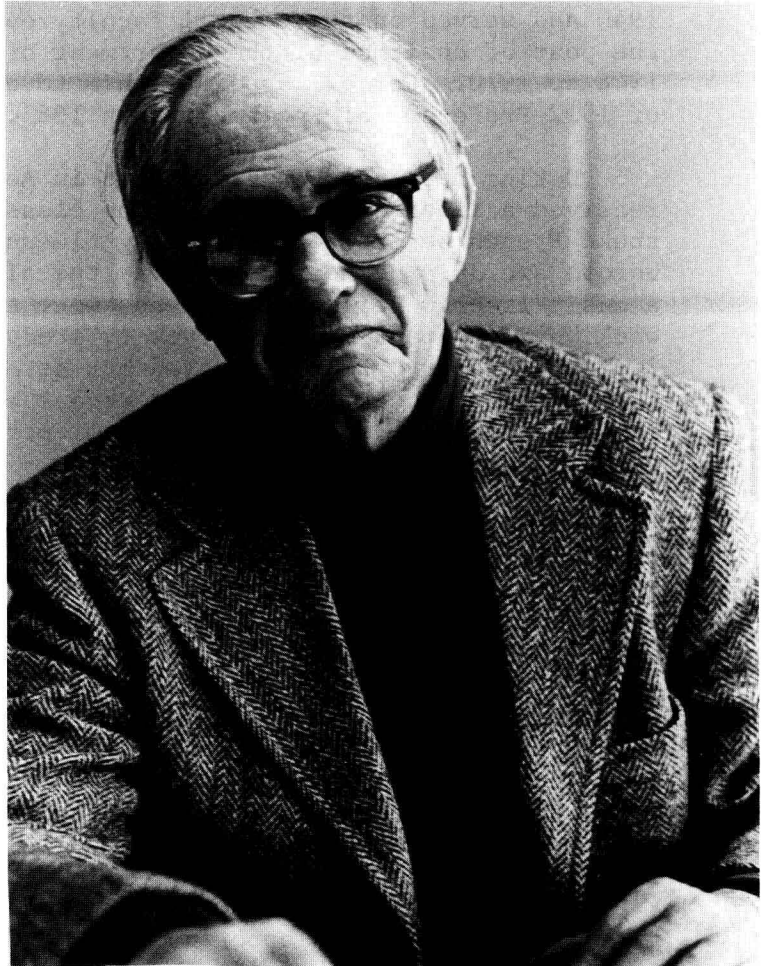
September 30, 1982 saw the conclusion of my four years as Chairman of SSRC. I can say sincerely that it was a lot of work but that I enjoyed it - especially because of the cooperation and assistance of the entire membership. I thank each of you for this help. Special thanks is due to Lynn Beedle, our Director, Lesleigh Federinic, our Administrative Secretary and Gulay Askar, past Technical Secretary, as well as all the other members of the Executive Committees during my time in office. I leave you now in the very able hands of your new Chairman, John Springfield and new Vice Chairman, Samuel Errera and I pledge to them my continued support and assistance as they initiate a new leadership with new ideas and plans for the Council.



Jerome S.B. Iffland
Structural Stability Research Council
Chairman, 1979-1982
New York, New York

In Memoriam

PROFESSOR GEORGE WINTER
1907-1982



Professor Winter died suddenly on 3 November 1982, in Ithaca, New York, following a coronary attack. He had enjoyed excellent health all his life, and was carrying forward his usual professional schedule at the time of his death. His numerous engineering friends and colleagues all over the world are left with a profound feeling of personal and professional loss. The news was particularly grievous to George's fellow members of the SSRC Executive Committee, who had enjoyed his company and benefited from his participation at their regular fall meeting only two weeks earlier.

George Winter was born and raised in Vienna. He came to the United States in 1938 to take up a graduate fellowship at Cornell University. He was awarded the Ph.D. degree in structural engineering in 1940 and served on the Cornell faculty over the next 35 years, holding the post of chairman of the department of structural engineering from 1948 to 1970. Cornell appointed him to an endowed chair as the Class of 1912 Professor of Engineering in 1963.

During his undergraduate years in Austria and Germany, George received a liberal education in the classical European tradition. "He spoke French before German, adding fluency in English and Russian before age 30. He learned to play the piano when quite young and remains a music lover. He and his friends went to concerts once or twice a week, having prepared themselves by studying the scores beforehand... It was customary, too, that students attend one of the many excellent theaters every week. They would choose a play to be performed, read it, and try to place it in historical perspective. And Vienna boasted great museums..." *

Following his graduation from the Technical University of Munich in 1930, George took employment in the construction industry. "His first job was working on the construction of Vienna's first skyscraper apartment house. The building still stands, but the company that built it collapsed in the depression. George became one of the large number of foreign specialists who found work in Russia during the first Five Year Plan... There were many professional challenges for him as well as a teaching assignment at the mining institute in Swerdlowsk. His wife, Anne, whom he married in Vienna in 1931, taught at the State Conservatory, and for both of them their Russian sojourn was professionally successful."

The Winter's move to the United States, and George's graduate fellowship and faculty opportunities at Cornell University, were implemented through the aid of several individuals including the late Dean S. C. Hollister; and by the end of 1940 George was launched into what soon became a distinguished academic career. One of the first things that Dr. Winter's students discovered about him was that here was a teacher and researcher who had practiced and understood the art of structural design. While George's lectures and research work were well fortified with theory, he invariably had his eye on an outcome that could be applied on a practical basis. What student could ever forget the typical Winter lecture? "The atmosphere which he consistently creates in the classroom is exhilarating; the clarity, the stimulation, the thought-provoking questions, the personal interaction, the sincerity, the dedication -- all of these things and more make his teaching both a challenge and an excitement."

* An excellent review of George's personal and professional life is given as the preface to "The Collected Papers of George Winter," published in 1975 by Cornell University upon his retirement from the faculty. This quotation and the others that follow are taken from that source.

While George's major professional contribution has undoubtedly been as a teacher, he wielded a vast influence on other areas of structural engineering. He became an international leader in structural research in three major materials: structural steel, light-gage steel, and reinforced concrete. He lectured widely on those subjects, and held visiting professorships at other leading institutions from time to time. Further, he was skilled in the art of translating research information into practical specification provisions for design use, and served with distinction on code-writing committees for each of those three materials.

George Winter shared his structural engineering insights and developments with the engineering profession and the public by means of a heavy schedule of writing. He was co-author of a widely used textbook on concrete, contributed to structural engineering handbooks and to the Encyclopedia Britannica, and authored or co-authored some eighty technical papers -- selections of which are included in the volume of collected papers referred to heretofore. "As a researcher and thesis advisor, his standards are of the highest. His own ability to use language with an uncanny skill leads him to insist on clarity, organization and pertinence. When writing and correcting papers, theses and reports, he wields the pen like a rapier, with awesome effect." What student or researcher ever walked (or sometimes even staggered!) away from a Winter review of his draft material without the feeling that his work had been through the wringer -- and had turned out all the better for it?

But professionalism, for all its importance in Professor Winter's life, is by no means the whole story. "In the case of George Winter the dynamics of art, music, philosophy, politics, and nature pervading Vienna of the 1920s continue to be evidenced in a man who has been not only chairman of Cornell's department of structural engineering for twenty-one years, but also a member of the University Planning Committee, the Engineering College Policy Committee, and the Steering Committee of the Program on Science, Technology and Society; and chairman of the University Lecture Committee, the Faculty Committee on Music, and Friends of Music. Always George urged his students to make use of Cornell's offering of horizon-widening experiences. He led them beyond an appreciation of structural engineering, recommending a special lecture or a good concert to his classes."

During his long and distinguished career Professor Winter accumulated a most impressive list of honors and awards, including an honorary doctorate from his undergraduate university; the Moisseiff Award, the Croes Medal, and the Howard Award of the ASCE; the Wason Medal and the Turner Medal of the ACI; and the International Award of Merit in Structural Engineering of IABSE. He was elected a Fellow of ACI, a member of the National Academy of Engineering, and an Honorary Member of ASCE.

As a particularly fitting memorial, the George Winter Graduate Fellowship in Structural Engineering has been established at Cornell University in his memory.*

* Contributions may be sent to Department of Structural Engineering, Hollister Hall, Cornell University, Ithaca, N.Y. 14853

Finally, we take note of Dr. Winter's significant contributions to the Structural Stability Research Council and its predecessor organization the Column Research Council. He was active in CRC/SSRC affairs over a 34-year period commencing in 1948, serving as a member or as chairman of several committees and task groups. He was a member of the Executive Committee continuously since 1962, and served as SSRC Chairman for the four-year period 1975-78. It was under his instigation and chairmanship that the new, broader name Structural Stability Research Council was adopted in 1976.

As we look ahead to the future of SSRC, it is evident that George Winter's devoted and noteworthy service on the Council and its Executive Committee will be greatly missed by his fellow members. In recognition of his substantial contributions to the work of the Structural Stability Research Council, and of his notable achievements in structural stability theory, research and practice, over an extended period, we have designated the forthcoming North American session of the Third International Colloquium on Structural Stability, to be held in Toronto on 9-11 May 1983, as "The George Winter Memorial Session" of the Colloquium.

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SSRC Executive Committee

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J. L. Durkee	- Consulting Structural Engineer
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G. Winter	- Cornell University



Back row: R. M. Meith, W. A. Milek, J. Springfield, J. S. B. Iffland,
J. L. Durkee, L. S. Beedle

Front row: L. G. Federinic, D. R. Sherman, G. F. Fox, B. G. Johnston,
G. Winter, S. J. Errera

Annual Technical Session

One of the purposes of the Council is to maintain a forum where the structural stability aspects of metal and composite metal and concrete structures and their components can be presented for evaluation, and pertinent structural research problems proposed for investigation. The Annual Technical Session provides an opportunity to carry out this function.

The 1982 Annual Technical Session was held on March 30 and 31 at the Rault Center Hotel, New Orleans. One hundred sixty-four persons attended the sessions and thirty-one papers were delivered.

A panel discussion on "Stability of Offshore Structures" was held in the evening of March 30, 1982. The panelists were P. W. Marshall, C. D. Miller, and J. R. Lloyd. The moderator was R. M. Meith.

This year's panel discussion was preceded by a special afternoon "Off-shore Session". C. D. Miller presided over the session which featured papers on research in the United States, United Kingdom, Norway, Japan and Israel.

In conjunction with the Technical Session, an Annual Business Meeting was held for the purpose of electing new officers and members, approval of the budget, and discussion of other business matters.

Papers presented at the offshore session, panel discussion and summaries of the technical session papers are recorded herein. An attendance list and minutes of the Annual Business Meeting are also included.



S. J. Errera, Sessions Program Committee Chairman

P R O G R A M O F T E C H N I C A L S E S S I O N

Tuesday, March 30, 1982

8:00 a.m. - REGISTRATION

9:00 a.m. - MORNING SESSION

Presiding: S. J. Errera, Bethlehem Steel Corporation

INTRODUCTION

J. S. B. Iffland, SSRC Chairman

L. S. Beedle, SSRC Director

9:10 a.m. - TASK GROUP 1 - CENTRALLY LOADED COLUMNS

Chairman: R. Bjorhovde, University of Arizona

- . Some Improvements to the Buckling Design of Centrally Loaded Columns

R. Maquoi, Universite de Liege

9:25 a.m. - TASK GROUP 3 - BEAM-COLUMNS

Chairman: J. Springfield, Carruthers and Wallace Limited

- . Ultimate Strength of Concentrically and Bi-Eccentrically Loaded Single Angle Columns

Z. Y. Shen, X. R. Hu, L. W. Lu, Lehigh University

9:40 a.m. - TASK GROUP 4 - FRAME STABILITY AND COLUMNS AS FRAME MEMBERS

Chairman: J. S. B. Iffland, Iffland Kavanagh Waterbury, P.C.

- . Bracing Stiffness Requirements for Braced Frames

C. Matsui, Lehigh University

- . Stability Analysis of Simple Frames with Semi-Rigid Joint Connections

G. J. Simitses and A. S. Vlahinos, Georgia Institute of Technology

- . The Effect of Various Directions of 3-D Seismic Inputs on Inelastic Buildings Based on INRESB-3D-82

F. Y. Cheng and A. J. Volker, University of Missouri-Rolla

10:25 a.m. - BREAK

10:45 a.m. - TASK GROUP 13 - THIN-WALLED METAL CONSTRUCTION

Chairman: W. W. Yu, University of Missouri-Rolla

- . Interactive Buckling in Plate Structures

S. Sridharan, Washington University

- . Ultimate Strength of Concentrically Loaded Cold-Formed Angles

M. K. S. Maduguta, M. C. Temple and T. S. Prabhu, University of Windsor

P R O G R A M

- 11:15 a.m. - TASK GROUP 18 - UNSTIFFENED TUBULAR MEMBERS
 Chairman: D. R. Sherman, University of Wisconsin-Milwaukee
- . Local Buckling of Steel Tubular Columns
 D. Grimm, McDermott Incorporated
- 11:30 a.m. - TASK REPORTER 16 - STIFFENED PLATE STRUCTURES
 A. Mansour, University of California, Berkeley
- . Structural Reliability and Strength of Stiffened Plates
 A. Mansour, University of California, Berkeley
- 12:00 noon - LUNCH
- 1:15 p.m. AFTERNOON OFFSHORE SESSION
 Presiding: C. D. Miller, Chicago Bridge and Iron Company
 Recorders: D. A. Ross, University of Akron
 S. X. Gunzelman, Brown & Root, Inc.
- 1:30 p.m. . Research in United Kingdom in the Stability of Circular Tubes
 P. J. Dowling, Imperial College of Science and Technology
- 2:00 p.m. . Research in Norway in the Stability of Circular Tubes
 G. Foss, Det Norske Veritas
- 2:30 p.m. . Research in U.S.A. in the Stability of Circular Tubes
 D. R. Sherman, University of Wisconsin-Milwaukee
- 3:00 p.m. . Research in Japan in the Stability of Circular Tubes
 Y. Kurobane, Kumamoto University; T. Atsuta, Kawasaki Heavy Industries Ltd.; S. Toma, Hokkai-Gakuen University
- 3:30 p.m. . Shell Buckling Research in Israel
 J. Singer, Israel Institute of Technology
- 4:00 p.m. . Stability Under Hydrostatic Pressure and Axial Tension
 R. K. Kinra, Shell Oil Company
- 4:30 p.m. - CHEVRON U.S.A. INC. RECEPTION
 R. Regl at piano

P R O G R A M

6:00 p.m. -

8:15 p.m. PANEL DISCUSSION: "STABILITY OF OFFSHORE STRUCTURES"

Moderator: R. M. Meith, Chevron U.S.A. Inc.

Recorders: P. C. Birkemoe, University of Toronto

T. A. Bubenik, Exxon Production Research Co.

Panelists: P. W. Marshall, Shell Oil Company

- . An Overview of Recent Work on Cyclic Inelastic Behavior and System Reliability

C. D. Miller, Chicago Bridge and Iron Company

- . Stability Considerations in the Design of Circular Tubes as Members of Offshore Structures

J. R. Lloyd, Exxon Production Research Company

- . Framing Patterns and Their Effect on Jacket Stability

Wednesday, March 31, 19828:30 a.m. - MORNING SESSION

Presiding: J. Springfield, Carruthers and Wallace Limited

- TASK REPORTER 13 - LOCAL INELASTIC BUCKLING

L. W. Lu, Lehigh University

- . Local Overall Mode Interaction

G. Askar, Lehigh University

8:45 a.m. - TASK REPORTER 14 - FIRE EFFECTS ON STRUCTURAL STABILITY

K. H. Klippstein, U. S. Steel Corporation

- . Stability of Fire Exposed Structural Steel Building Floors - A Computer Model and Full-Scale Test

D. C. Jeanes, American Iron and Steel Institute

9:00 a.m. - TASK GROUP 14 - HORIZONTALLY CURVED GIRDERS

Chairman: C. H. Yoo, Auburn University

- . Out-of-Plane Buckling of Circular Rings

C. H. Yoo, Auburn University

9:15 a.m. - TASK GROUP 16 - PLATE GIRDERS

Chairman: M. Elgaaly, Bechtel Associates

- . Stress Distribution of Buckled Shear Webs

C. Marsh, Concordia University

P R O G R A M

9:30 a.m. - TASK GROUP 21 - BOX GIRDERS

Chairman: R. C. Young, Iffland Kavanagh Waterbury, P.C.

- . Steel Box Girders Subjected to Torsion, Bending and Shear
A. Ostapenko, Lehigh University

9:45 a.m. - BREAK

10:05 a.m. - REPORT ON THE ECCS STABILITY PROGRAM

C. Massonnet and R. Maquoi, University of Liege

10:35 a.m. - TASK GROUP 23 - EFFECT OF END RESTRAINT ON INITIALLY CROOKED COLUMNS

Chairman: W. F. Chen, Purdue University

- . Strength of Imperfect H-Columns with Simple End Restraints
E. M. Lui and W. F. Chen, Purdue University
- . Limit States of Flexibly-Connected Steel Building Frames
M. H. Ackroyd, Rensselaer Polytechnic Institute
- . Construction of Variable End Restraints for Small Scale
Testing of Tubular Columns
D. A. Ross, University of Akron

11:20 a.m. - TASK GROUP 7 - TAPERED MEMBERS

Chairman: G. C. Lee, State University of New York

- . Full Scale Testing of Tapered Structural Members
D. L. Johnson, Butler Manufacturing Company Research Center
- . Web Crippling of Unstiffened Thin Webs Under Concentrated Load
G. C. Lee and J. H. Chern, State University of New York

11:50 a.m. - ANNUAL BUSINESS MEETING

12:30 p.m. - ADJOURN

T A S K G R O U P R E P O R T S

TASK GROUP 1 - CENTRALLY LOADED COLUMNS

Chairman, R. Bjorhovde, University of Arizona

Some Improvements to the Buckling Design of Centrally Loaded Columns

R. Maquoi, University of Liege

Let me first tell you that this contribution reflects a work to which Assist. Prof. RONDAL has contributed with me, in the department of Professor MASSONNET.

In the foreword of the third edition of what is commonly designated by the "Guide" - I mean the "Guide to Stability Design Criteria for Metal Structures" -, I read that "the name of Column Research Council was changed to Structural Stability Research Council to reflect the broadened scope it has assumed during the more than 30 years of its existence". I observe that this change of designation coincide nearly with the solution of the most simple stability problem: the buckling of the centrally loaded column. That means that a satisfactory solution of this problem took several centuries. Indeed, the first physical model is attributed to DA VINCI and the first empirical formula suggested by VAN MUSSCHENBROEK is 250 years old. EULER formulated his well-known formula for the critical load in 1759 and NAVIER showed in 1826 that the Eulerian load is an upper bound. Then, two approaches are developed: the first one is concerned with the bar with imperfections and the second one is dealing with the inelastic behaviour.

In 1955, ECCS decided to perform a large series of tests and to simulate numerically the behaviour of the centrally loaded columns; as a result, three curves were proposed in 1970 and lightly modified afterwards so that 5 curves exist now in non dimensional coordinates, with a yield plateau up to a reduced slenderness ratio of 0.2.

The selection chart for these curves takes account of the type of cross-section, of the buckling axis and eventually the depth to breadth ratio. The ECCS curves correspond to characteristic values of residual stress and of initial imperfection, this latter being 1/1000 of the buckling length.

The three SSRC buckling curves called 1, 2 and 3 are very close to European curves a_0 , b and d respectively. European curves were only given by means of numerical tables and were thus not convenient for a use on a small desk computer. On the contrary, the SSRC buckling curves are given analytically but require 11 coefficients for curves 1 and 3 and 12 coefficients for curve 2.

TG-1

A first attempt was to find simple analytical expressions for the ECCS buckling curves and, why not, much more simple equations for the SSRC ones. For this purpose, a similar approach was used; it is based on a physical model: an imperfect bar centrally loaded is subject to an axial force N and to an amplified bending moment $M^{II} = K N e_o$. It is well known that the magnification factor K is different in case of an initial deflection of the imperfect bar or to a load excentricity in a perfect bar; however the numerical values are only slightly different and the magnification factor can be taken equal to $(1 - N/N_{cr})$. Using a collapse criterion according to which the ultimate strength is reached when the yield stress f_y occurs at the most compressed fiber, it is written:

$$\frac{N_K}{A} + \frac{M^{II}}{W} = f_y \quad (1)$$

or, in terms of stresses:

$$\sigma_K + \frac{\sigma_K}{1 - \frac{\sigma_K}{\sigma_{cr}}} \frac{e_o A}{W} = f_y \quad (2)$$

After some minor arrangements, one has the well-known AYRTON-PERRY like equation:

$$(\sigma_{cr} - \sigma_K) (f_y - \sigma_K) = \eta \sigma_{cr} \sigma_K \quad (3)$$

with the imperfection parameter:

$$\eta = \frac{e_o A}{W} = \frac{e_o A v}{I} \quad (4)$$

or by expressing e_o as a part $1/\gamma$ of the length L :

$$\eta = \frac{L}{\gamma i(i/v)} = \frac{\lambda}{\gamma (i/v)} \quad (5)$$