FORTY YEARS OF ENGINEERING STRUCTURES, MECHANICS AND CONSTRUCTION RESEARCH AT THE UNIVERSITY OF WATERLOO

Mircea Z. Cohn and Donald E. Grierson
Civil Engineering Department, University of Waterloo, Canada

"In order that they may live and bring forth life, generations must continue to meet, and the teaching assume the form of a human link, awakening and activating our bond with our Father. The spark that leaps from him who teaches to him who learns rekindles a spark of that fire which lifted the mountain of revelation to the very heart of heaven…" (Buber,1956).

Initial planning for the formation of the Solid Mechanics Division (SMD) at the University of Waterloo began in 1966, and it was implemented into a formal entity following the award of a National Research Council of Canada Development Grant in 1968. Upon the departure and retirement of many of its initial members over the next thirty years, SMD was reconstituted in the mid-1990s as the Structures Mechanics & Construction Division (SMCD) to reflect the changing research interests of its more recent and new members. The collective research work of both SMD and SMCD has resulted in many publications and valuable contributions to the progress of engineering structures, mechanics and construction. This paper presents a 40-year historical perspective through to 2006 of this activity at the University of Waterloo.

1. Introduction

In the early 1960s, the University of Waterloo was only a few years old and its Faculty of Engineering was just about to produce its first graduates. D.T. Wright, the founding dean and subsequently the University's third president, brought to the Faculty a number of promising scholars from around the world, and thus opened the prospects of vigorous progress in its innovative cooperative programs in engineering.

The Civil and Mechanical Engineering Departments acquired at the time a group of young faculty members eager to realize their academic potential and widen their research horizons. Under the leadership of A.N. Sherbourne, the next Dean of Engineering, new ways for enhancing existing capabilities of the two departments were explored. Their parallel or intersecting areas of activity in Mathematics, Theoretical and Experimental Mechanics, Soil Mechanics, Structural and Machine Analysis and Design, Material Science and Technology, etc., suggested that considerable benefits could be expected from closer cooperation and coordination of activities for groups with similar interests in the two departments.

Dean Sherbourne advanced the concept of bringing the above disciplines under a broad umbrella organism, that came to be known as the SOLID MECHANICS DIVISION (SMD), and initiated efforts to define its goals, structure and mode of operation, as well as means of formalizing its creation.

This paper describes the beginning, growth and maturing of SMD, as well as that of its successor, the STRUCTURES MECHANICS and CONSTRUCTION DIVISION (SMCD). The presentation gives a brief historical overview of these entities, offers a permanent record of results of their activities, examines the causes of related successes and failures, and draws some possible lessons from the first four decades of this academic experience.

M. Pandey et al. (eds), Advances in Engineering Structures, Mechanics & Construction, 3–29.

2. Solid Mechanics Division (SMD)

2.1. Beginnings

Prompted by Dean Sherbourne, a group of UW faculty decided to formalize the voluntary cooperation of members in the Civil and Mechanical Engineering Departments into a research unit, the Solid Mechanics Division (SMD). Its goal was to establish a centre of excellence in solid mechanics at the University of Waterloo (UW) by enriching the existing research and teaching programs. While the main emphasis was placed on the human factor (i.e., attracting outstanding visiting professors, research fellows and graduate students), serious consideration was also given to modernizing laboratory facilities and expanding the working environment and supporting staff.

Implementation of these general objectives was detailed in an application to the National Research Council (NRC) for a major negotiated grant to UW, aiming at the creation and development of SMD. In April 1968, NRC announced the three-year award of Grant D-10 in the amount of $600,000. The funds were to be expended in installments of $100,000, $200,000 and $300,000 in each year of the award term. It was the understanding of the grant applicants and of the Dean of Engineering that, whereas Grant D-10 was to help establish SMD as a centre of excellence, by the very nature of the grant UW was committed to ensuring its continuing existence and development through appropriate support and funding at the end of the award term.

Thus, SMD was brought to life in the spring of 1968 by a decision of the University Board of Governors and the generous NRC award of Development Grant D-10. One of the first tasks of the SMD steering group was to establish an administrative structure that could implement the stated objectives under the terms of Grant D-10. After considering to offer the chair to a distinguished foreign academic, the group ultimately decided to nominate, and the Faculty of Engineering appointed, M. Z. Cohn to fill that position for three years.

The founding SMD membership included Professors S. T. Ariaratnam, D. J. Burns, R. Green, N. C. Lind, J. T. Pindera, H. B. Poorooshasb, A. N. Sherbourne, T. H. Topper, and the founding SMD Chair, M. Z. Cohn. Other members that joined SMD soon thereafter and over the next few years were Professors E. F. P. Burnett, R. Dubey, G. M. L. Gladwell, D. E. Grierson, K. Huseyin, H. H. E. Leipholz, G. M. McNeice, T. P. Prasad, J. Roorda, R. M. Schuster and J. C. Thompson. It is of interest to note that the initial and early SMD membership was comprised of individuals from several different departments of the faculty of engineering, including Civil, Mechanical and Systems Engineering.

The SMD founding group and chairman agreed on a few basic operational principles:

- Minimal administration and formalism;
- Expectation of performance from key members with authority and responsibility;
- Clarity of objectives for efficient implementation.

The SMD operation was to be ensured by the following elements:

- Executive Committee, responsible for planning, funding and deciding on all activities;
- Publication Committee, in charge of policy matters for production of SMD publications;
- Area Representatives, responsible for initiating and overseeing activities in each area of concern (i.e., structures, computer analysis and design, geotechnical, mechanics, experimental mechanics, etc);
- Task Officers, responsible for three SMD major tasks: Publications, Seminars and Library.

Main operational features were the complete decision transparency of its working committees and total initiative and authority of each task officer. Monthly SMD meetings - not exceeding one hour - were planned and rigorously held in order to keep members informed in a timely manner on all matters of general concern.

D. E. Grierson was appointed as Publications Officer, a capacity in which he served throughout the life of SMD. Over the years he was assisted by a dedicated production staff, A special contribution was brought by D. Bartholomew of UW Graphic Services who designed the SM Studies jackets and all publication formats. His response to our exigencies produced the SM Logo shown in Figure 1, that soon become our well-recognized and proud emblem on all SMD printed output.

Figure 1. SM Logo

Bi-monthly SMD Seminars, initiated and regularly held on Mondays at 3:30-5:00 p.m., became a permanent entry in our calendars. SMD staff ensured the conservation and growth of library collections that included our own publications series, as well as solid mechanics volumes and journals donated by members.

2.2 Growth

SMD vision and ambitious program became apparent with the number and variety of its printed and verbal expressions. The main evidence of success in its activities was the body of SM publications that began to be produced within a short time, including the SM Studies Series, SM Papers/Report Series, SM Special Publications and the SM Archives Journal.

2.2.1. SM Studies Series

This, probably the most important and widely known of SMD products, is a collection of publications intended to record major contributions by the SMD at UW in Applied Mathematics, Solid Mechanics, Structural Analysis and Synthesis, Experimental Mechanics, and Philosophy of Design. The SM Studies Series makes available works of academic merit which, because of their content or volume, may not be published by scientific journals or as independent books. These include proceedings of seminars and symposia, monographs, research studies and significant doctoral dissertations. (The jacket cover for the first SM Study is shown in Figure 2).

The SM Studies Series was conceived in order to confer a character of permanence to valuable work initiated and completed by SM members and their associates, work that might otherwise be lost or forgotten. The series was published under the direction of an Editorial Committee consisting of S.T. Ariaratnam, M.Z. Cohn, H.E. Leipholz, N.C. Lind, J.T. Pindera and A.N. Sherbourne, with the cooperation of a group of external Consulting Editors of international reputation.

Members of the Editorial Committee led their colleagues by example, by making repeated contributions to the Study Series and other SMD publications in their areas of expertise as follows:

S.T. Ariaratnam: Dynamics, Stochastic Processes, Continuum Mechanics
M. Z Cohn: Structural Plasticity and Optimization, Concrete Structures
N.C. Lind: Reliability, Codified Design and Risk Analysis
H.E. Leipholz: Stability and Mechanics of Continua
J. T. Pindera: Experimental Mechanics
A. N. Sherbourne: Steel Structures, Shell Analysis and Design

Other SMD members at the time also made contributions to the various SMD publications in their areas of expertise as follows:

E. F. P. Burnett: Building Sciences
D. J. Burns: Engineering Mechanics
R. Dubey: Mechanics of Materials
G. M. L. Gladwell: Applied Mathematics
R. Green: Bridge Engineering
D. E. Grierson: Structural Optimization
K. Huseyin: Stability
G. M. McNeice: Finite Element Analysis
H. B. Poorooshasb: Soil Mechanics
T. P. Prasad: Applied Mathematics
J. Roorda: Structural Stability
R. M. Schuster: Cold-Formed Steel
J. C. Thompson: Experimental Mechanics
T. H. Topper: Materials Engineering

Figure 2. SM Study No. 1

Among the numerous Consulting Editors and friends of SMD and its publications, we remember the names of E. F. Masur (University of Illinois at Chicago), N. J. Hoff (Stanford University), C. P. Siess (University of Illinois), Ch. Massonnet (University of Liège), and M.R. Horne (Manchester University).

As the SM Studies Series became widely recognized, foreign scholars found it a congenial medium for disseminating results of their work and began organizing and publishing conference proceedings using SMD and UW Press facilities (e.g. see Appendix 1: Studies 12, 15, 16 and 17).

The reputation of SMD and its SM Studies Series may be attributed to its:

- Broad range and depth of areas covered;
- Quality of contributors and their contributions;
- Balance between theory and practice of engineering, classical and modern views, and fundamental and applied research;
- Innovative and outstanding doctoral dissertations (e.g., see Appendix 1: Studies 2 and 4).

It is worth mentioning that the graphic excellence of the SM Studies Series has been a major factor in its broad recognition, due in no small measure to the striking jacket design sporting the SM Logo in different colours for each volume. As listed in Appendix 1, eighteen volumes were published in this series between 1969 and 1988. (The jacket covers for two representative SM Studies are shown in Figure 3).

Figure 3. SM Studies 9 and 14

2.2.2. SM Papers, Reports and Notes Series

A second series of publications was the *white-cover* SM Reports/Papers Series, intended to ensure rapid dissemination, reaction and comment on papers prior to formal publication in refereed technical and scientific journals. As listed in Appendix 2, this series ran for 199 issues from 1969 to 1985. The series was initially called SM Reports , but its name was changed to SM Papers beginning with issue 101 in order to better reflect the nature of its contents. (The front cover of the first issue in the series is shown in Figure 4).

Figure 4. SM Report/Paper No. 1

The *blue-cover* SM Technical Notes/Reports Series was devoted to materials that deserved preserving for specialized study, but which, because of the type of information or volume, would not be normally published in standard periodicals. As listed in Appendix 3, this series ran for 31 issues between 1971 and 1980, and includes texts presented at various congresses, documents with extensive numerical or experimental data, and computer programs. The series was initially called SM Technical Notes, but its name was changed to SM Reports beginning with issue 15 in order to better reflect the nature of its contents. (Part of the front cover of the first issue in the series is shown in Figure 5)

Figure 5. SM Technical Note/Report No. 1

Solid Mechanics Archives **Volume 1, No. 1, 1976**

S. K. Srinivasan
Stochastic models for fatigue failure of materials 3

C. E. Massonnet
Forty years of research on beam-columns in steel 27

Solid Mechanics Archives **Volume 14, Nos. 3 & 4, 1989**

H. H. E. Leipholz
Obituary: 1919 – 1988 129

N. Sri Namachchivaya
Instability theorem based on the nature of the boundary behaviour for one-dimensional diffusion 131

S. A. Soliman and R. N. Dubey
On stiffness matrices in finite element analysis of isotropic elastic Solids 143

S. T. Ariaratnam and Ashwini Kumar
On eigenmodal deformations in incompressible elastic solids under dead loads 149

P. Labossiere and K. W. Neale
On a parametric failure theory for fibre-reinforced composite Laminae 157

T. Lekszycki and Z. Mroz
Variational principles in analysis and synthesis of elastic systems with damping 181

Tian-quan Yun
Dynamic instability of axisymmetric dimpled shallow spherical Shells 203

L. Librescu and N. K. Chandiramani
Recent results concerning the stability of viscoelastic shear deformable plates under compressive edge loading 215

Figure 6. Contents of First and Last Issues of SM Archives Journal

2.2.3. Solid Mechanics Archives

In 1976, SMD initiated and directed the publication of SM Archives, a quarterly International Journal, dedicated to original contributions to solid mechanics. It was printed with the cooperation of Noordhoff International Publishing, The Netherlands, and Oxford University Press, U.K. The Journal was under the direction of internal and external editorial boards, and appeared in 14 volumes until 1989. (The Contents for the first and last journal issues are shown in Figure 6).

2.2.4. SM Special Publications

Over the years a number of volumes were occasionally published outside the range of the regular SM series. These somewhat randomly-produced texts are of two distinct types:

- Lectures Sets given at UW by SMD members or visiting guests;
- Textbooks, Manuals, and Conference Proceedings sponsored by external agencies.

Some of these texts were organized and edited by SMD members, but produced by commercial publishers. A heterogeneous collection, the SM Special Publications cover a wide spectrum of interests within recognized SMD areas of expertise, while addressing an audience reflective of the international sponsoring organizations. A partial listing of the Special Publications is given in Appendices 4 and 5. (The partial front cover of a representative SM Special Publication is shown in Figure 7).

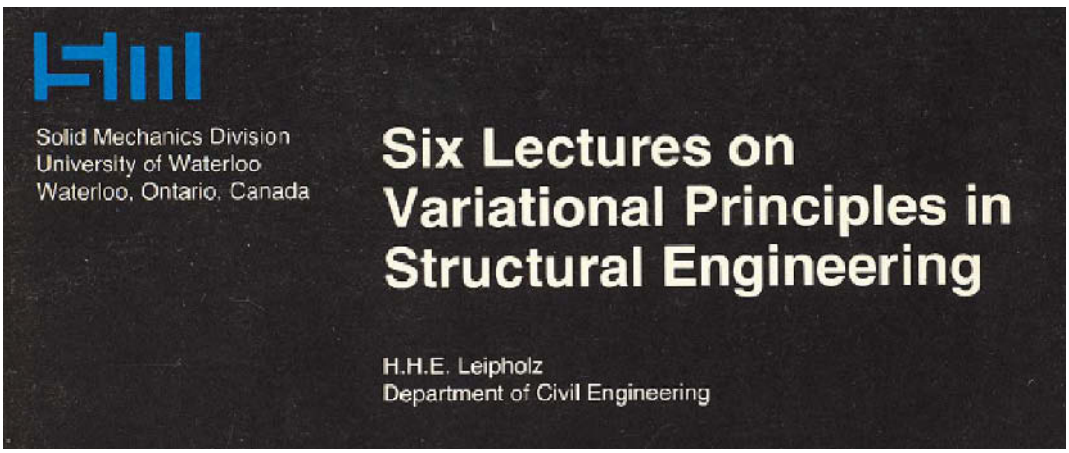

Figure 7. Representative SM Lecture Set

2.3. Maturity

Processes of learning and sharing technical knowledge constituted the permanent focus of SMD activities, not only through the printed medium, but also by direct personal interaction of Division associates and visitors. Such interaction found its expression in various seminars, workshops, conferences and symposia, as well as lectures by invited guests on topics within the stated SMD mission.

A systematic listing of all SMD live-events is rather difficult to achieve because of the variety of venues (Waterloo or elsewhere), sponsorships (SMD, other, combined), publishers (UW or other), and orientation (research or teaching). A sample of the major events with SMD involvement is given in Appendix 6. The publication activities for these events have been surveyed in the preceding section. We now turn our attention to communication events of either research or teaching orientation.

2.3.1. Research-oriented Events

From the late 1960s to the early 1980s a number of topics in solid mechanics captured the interest of investigators around the world. At the time SMD was a centre of exciting developments in structural plasticity and optimization, reliability and codification, and stability and experimental mechanics. Interaction of SMD faculty, associates, students and friends allowed the planning and organizing at Waterloo of some notable international meetings on these topics. Images of the delegate participation at three such events are shown in Figures 8, 9 and 10.

Figure 8. NATO ASI- *Engineering Plasticity by Mathematical Programming*, Waterloo 1977

Figure 9. International Symposium-*Nonlinear Design of Concrete Structures,* Waterloo 1979

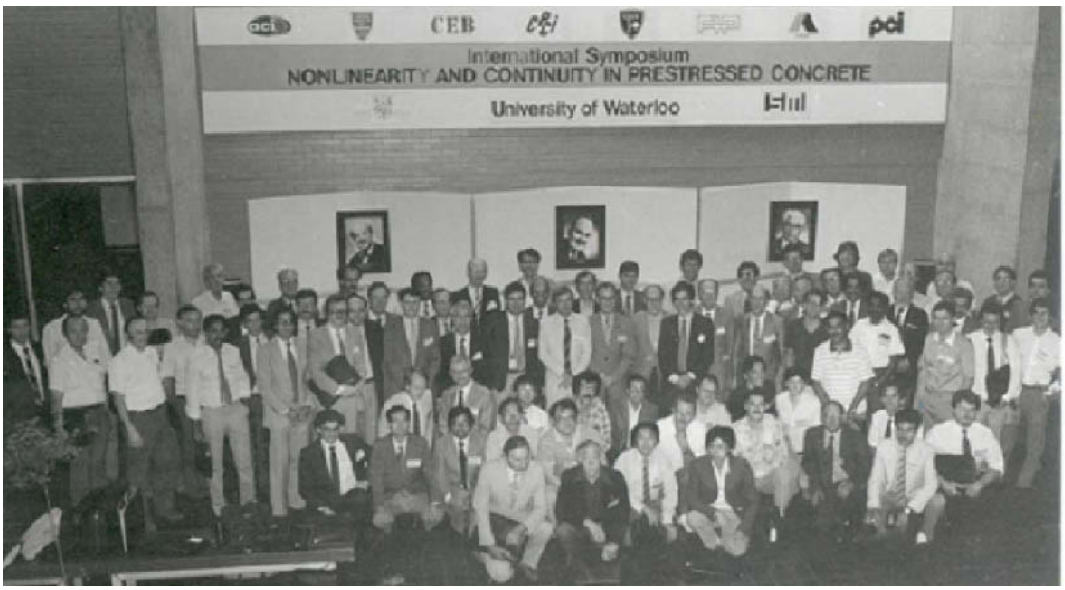

Figure 10. Int'l Symposium-*Nonlinearity and Continuity in Prestressed Concrete*, Waterloo 1983

The first SMD meeting was the *Colloquium on Limit Design for Structural Concrete,* September 6-8, 1967. The purpose of the meeting was to clarify the theory and practical design application of three methods of Limit Design under debate by the joint ASCE-ACI Committee 428. The premises and feasibility of the three (European, American and Canadian) approaches were each discussed for one full day, with the basic principles presented by their authors during the morning sessions. Three representative structure examples, fully worked out by the Waterloo group of faculty and graduate students, were presented in the afternoon sessions. The latter results are summarized in the first issue of the SM Paper/Report Series (Cohn et al, 1969). The 1967 meeting was the beginning of an intense activity of live-events, whose contents and output is reflected by the Special Publications reviewed in the preceding section (see Appendix 6).

2.3.2. Teaching-oriented Events

The extent of advanced teaching by SMD and visiting faculty members may be assessed from the related printed documents listed in Appendix 4. While these lecture sets were mainly addressed to graduate audiences, SMD was equally interested in enhancing the overall quality of undergraduate teaching of solid mechanics at UW, consistent with its basic mandate. In this regard, during the 1969 summer semester SMD organized a weekly seminar cycle designed to stimulate undergraduate teaching excellence so that it would match our high graduate programs standards. Some of the problems and dilemmas identified but unsolved were mainly consequences of the distinctive features of UW's engineering education, particularly the cooperative work-study program and the related academic calendar. Also of concern were the handling of the general knowledge explosion, new directions of study, and their accommodation within the curricula of standard four-year study programs. A fresh outlook on the design of undergraduate teaching seemed unavoidable if the following topics were to be properly addressed:

- Role of solid mechanics in CE and ME curricula;
- Nature of SM teaching output (engineers or engineering scientists);

- Optimal teaching techniques (lecturing, problem solving, laboratory work, projects, TV sessions, etc.);
- Optimal mix of various areas of study (mathematics, physics, computer techniques, theoretical and applied mechanics, etc.)
- Objective teaching evaluation ("delivery" or "retention" models).

Specific questions pertaining to objectives, major topics, minimal ingredients, significance and optimal instructional media for each individual course were explored. Some of the major flaws identified in solid mechanics courses were: coverage of basic statics, insufficient laboratory work, poor understanding of physical problems and role of modelling, inefficient tutorials and insufficient engineering project work. Furthermore, it was strongly felt that lack of coordination of CE and ME offerings was manifest in unnecessary repetitions, omissions or redundancy, along with unsuitable textbooks and inadequate lecture-tutorial coordination.

A comprehensive discussion of the above problems took place in the framework of 12 weekly seminars during the 1969 summer term. Each seminar was devoted to one course presentation and full debate by faculty members and students with a view to:

- Establishing quality standards for the teaching process;
- Developing lecture notes, laboratory manuals, problem sets and other teaching aids tailored to the specific needs of UW students and their cooperative programs;
- Developing and completing within a few years an integrated set of *SM Textbooks* that encapsulated UW needs and standards, to be known as the SM Text Series.

The 1969 summer term SM Teaching Seminars were well prepared, attended and debated and generated productive discussion by the participants. Regrettably, the perseverance and long-term motivation required for bringing this major project to fruition were lost with time and the concept of a complete, modern SM Text Series, unified in format and educational perspective, failed to materialize. However, a lonely sample of the potential of this ambitious project saw the light of day in 1972 (Cohn 1972), and remains a prototype of what might have been the outcome of staying on course with our initial vision. (The partial jacket cover for the sole publication in the SM Text Series is shown in Figure 11).

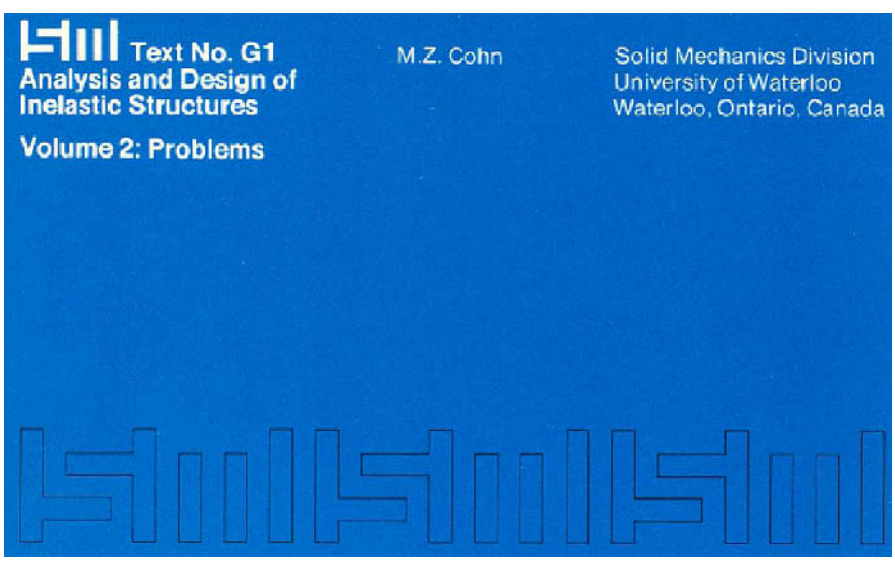

Figure 11. SM Text No. G1

2.3.3. Visiting Scholars

The maturing of SMD is convincingly illustrated by its wide recognition by scholars from all continents and their interest in visiting UW for cooperative projects with our faculty and students. As it would be difficult to list all our distinguished guests and to identify the centres of learning with which SMD has established and developed most productive contacts over the years, we mention below only some of the most prominent guests.

Among many others, SMD was honoured to host such eminent personalities as W. Prager (University of San Diego), A. L. L. Baker (Imperial College, London), F. Levi (University of Torino), C. Menn (ETH, Zurich), J. Muller (Paris, France), G. Maier (Politecnico, Milano), F. Moses (Case Western University), Z. Mroz (Technical Research Institute, Warsaw), N. Khachaturian (University of Illinois at Urbana), and L. A. Schmit (UCLA).

2.3.4. Late Years

Three years after its promising beginnings and depletion of the funds awarded through NRC Grant D-10, the SMD autonomy started to be eroded; the promised continuing financial support by UW administration, implied by the negotiated grant, did not materialize; CE and ME departments favoured the parochial management of their traditional territories; SMD involvement in the planning and delivery of undergraduate programs was grossly misunderstood.

A 1972 UW Senate decision put an end to the formal existence of SMD. Its ongoing activities were to be carried out through departmental channels, with a small stipend granted from the CE department budget. SMD chairmanship was reassigned to H. E. Leipholz, who served from 1972 to 1979, when he assumed a senior position in the university administration. With the era of major initiatives and innovations being over, Leipholz must be credited for having maintained some of the activities and original SMD ways.

As a sign of the emerging hard times, SMD members volunteered to make individual financial contributions in order to sustain on a limited scale the planned projects and events. With SMD turning from a living organism to a surviving name and a bright memory, it became the task of G. M. L. Gladwell in 1979 to serve as the chair of the once proud and independent research group.

3. Critical Remarks

3.*1. Successes*

Statistical data regarding SMD activities can only give a limited view of its successes. Yet, it is noteworthy that in just the first three years of existence its printed output amounted to six SM Studies, one hundred SM Papers and fourteen SM Reports. During the same period it organized four major symposia and lecture series, and established a bi-weekly seminar series as a permanent forum for scholarly presentation and discussion. These accomplishments were multiplied within the next two decades of rather fragile survival, as shown by Appendices 1 to 6.

Beyond statistical facts, major successes must be credited to A.N. Sherbourne's initiative of integrating individual strengths into a cross-departmental focused entity, and to SMD's founding members for shaping it so that the division could represent more than the sum of its individual components. Indeed, in a short time span, the collective formal unit that embodied the members' confidence, dedication and pride produced a noticeable rise in the level and dissemination of research results.

The principal SMD achievement consisted of living up to an uncompromising commitment to excellence, marked by a constant promotion of new young talent, individual growth, group development and international cooperation. The SMD reputation can be measured by the calibre of people associated with the wide range and high quality of its activities.

These were distinctive not only in substance, but also in a style expressed by the graphic standards and formats of its publications, as well as by the sense of occasion, attention to detail and meticulous organization of conferences. Not to be forgotten are the musical themes used as inspirational motifs, calls to order for working sessions or relaxing interludes.

What were the means that made possible the above successes? The essential factor was the rich reservoir of individual talent. But existing potential might not have materialized without the financial support of NRC Grant D-10.This award confirmed the viability of the SMD visionary program, energized its members and stimulated their creativity. Although relatively modest even by 1970s standards, the award funds were sufficient for initiating a large number of projects in a short time. However, we believe that, even with proper funding, SMD program could not have been implemented had it not been animated by the concepts of personal autonomy and responsibility, along with collective involvement and transparent leadership.

The establishment of the SMD Centre in 1972 in the E-4 (Pollock) Building had a very positive impact on the efficiency of its operation. Conceived, designed and furnished with active SMD participation, the Centre provided adequate space for SM faculty and graduate students, secretariat offices, library, lounge and a fully equipped seminar room. These facilities ensured precious proximity and improved the interaction among faculty, students and staff, as well as with laboratories and computer rooms.

3.2. *Failures*

Successes and failures can be assessed by comparison to either adopted or desirable objectives. By the first criterion SMD has to be characterized as an overall success, because it delivered on 100% of all contracted obligations.

By the second criterion, the projected self-imposed development and production of the SM Text Series, following the summer 1969 teaching seminars (see *2.3.2*), ended as a serious failure. Completion of this project might have represented a unique contribution to the teaching of solid mechanics at the University of Waterloo. Ironically, while this initiative gave a constructive response to the often heard criticism that faculty members were more interested in research than teaching, it probably generated a political malaise responsible for the negative attitudes of Civil and Mechanical Engineering Departments toward SMD and its future. SMD efforts were aimed at reviewing the curricula, rationalizing inter-departmental programs and improving their implementation, *without* involvement in, or change to existing administrative structures. Sadly, departments misread our intentions, fearing an encroachment of their jurisdiction, power, and decision-making authority.

Beside the above, the critical SMD failure was an existential one. Although decisions on its fate were beyond the will and power of our group, a more outspoken response could have been given when SMD formal status was questioned and finally revoked. The UW reneging on the initial commitment to sustain its hard won centre of excellence brought disbelief, consternation, and eventual resignation to SMD membership.

It is fair to note that the political winds changed considerably during the short period of time since SMD inception: whereas the dominant orientation in the late 60's was toward fundamental research and outward-looking, the early 1970s saw a switch to applied, nationally profitable research and development. UW followed the trend of chasing funding opportunities by downsizing long-term pursuits in favour of reaching tangible material benefits in the shortest possible time. It was in this climate that extensive debates took place on research policies related to basic vs. mission-oriented development, federal vs. provincial jurisdictions, the role of research in university vs. government labs, or industry. UW's position may be inferred from the words of its Academic Vice-President at the time (Petch 1973):

There are three areas in which debate is still hot, with little indication that agreement will soon be reached: funding university research, organization of government research and stimulation of innovation in industry. (p.40)

Basic research has been one of the chief targets of those critical of the government's policy, or lack of policy, on scientific matters. In moments of passion, some critics have suggested that Canada should divert all financial support to applied research and development and phase-out basic research. (p.36).

The demands for more mission-oriented basic research, applied research and development, arise because of a wide-spread feeling that Canada must utilize science and technology more in striving to achieve national goals, coupled with a new understanding that benefits do not necessarily flow automatically from free basic research, but require a conscious effort at application. (p.38).

3.3. Lessons

SMD was a memorable episode in the UW Faculty of Engineering: great talent and work pre-existed its creation and subsisted its demise. But its early years energized and brought out the best of existing potential and raised it to a level of high academic distinction and achievement. Not only did SMD live up to its commitments, but it amply exceeded the expectations of its founding members and caused our university to be recognized as a real force in the world of solid mechanics.

While we started this survey with the intention of factually recording the SM activities over approximately the last forty years, we may be excused if the intended writing objectivity has suffered occasionally: some of the old passion for SMD ideals could not be entirely eliminated while undertaking this memory trip.

Perhaps we may also be indulged in a little literary flight of fancy by viewing the SMD story as a real academic saga with not a few rather dramatic ingredients: indeed, on a close look, the evolving process of creation, development, stagnation and renewal are quite obvious. However, the less obvious conflicts of authority between an old departmental structure and a superimposed (perceived) rival new entity, jealousy and personality clashes, tradition versus innovation, loyalty and deception, growth, decay and redemption, all major themes of the classic drama are, or may be assumed, as part of this narrative. And so might have been pain, dissatisfaction, disappointment, and resistance to change, which are seldom absent at transitions from old to new.

Yet, in spite of all the ups and downs, a dominant leit-motif is discernible throughout the entire SMD project: fostering learning and inspiring human interaction between the old and the young, regardless of contingent circumstances. Whether funded adequately or not at all, the commitment to excellence was, and apparently will remain, the leading motivation of the UW group of scholars active in the fields of structures, mechanics and construction.

4. Structures, Mechanics and Construction Division (SMCD)

4.1. An Ongoing Commitment

G. M. L. Gladwell served as chair of SMD from 1979 to 1992. A thirteen year period over which, despite the noted difficulties, the membership continued to act as a loosely-knit research group; collaborating on research projects, coordinating seminars, pooling resources to support visitors, and participating in the hiring of new faculty. The group has maintained an ongoing commitment to research and its related activities through to the present day. D. E. Grierson served as chair from 1992 to 2002, while G. W. Brodland continues as chair to 2006 and beyond.

Upon the departure and retirement of nearly all of its initial and early members over almost 30 years since its inception, SMD was renamed in the mid-1990s as the Structures, Mechanics and Construction Division (SMCD) to reflect the changing research interests of its more recent and new members. Professors Brodland, W.-C. Xie and M. A. Polak joined SMD/SMCD during the late 1980s and early 1990's; M. Pandey, K. Soudki, T. Hegazy and L. Xu joined in the mid-1990s; J. Straube, J. West and S. Potapenko joined in the late 1990s and early 2000s; while S. Narasimhan and S. Walbridge became new members as of May 1, 2006.

4.2. SMCD Member Research Interests

The present-day membership of SMCD consists of individuals from the Department of Civil Engineering. A brief sketch of each member's research interests is given in the following.

G. Wayne Brodland: advanced computational models for tissue and cell mechanics; unique instrumentation and software for data collection and analysis; and development of a unified theory of embryo mechanics.

Wei-Chau Xie: structural dynamics and random vibration, reliability and safety analysis of engineering systems, dynamic stability of structures, nonlinear dynamics and stochastic mechanics, localization in randomly disordered engineering structures, vibration design of residential floor systems using cold-formed steel joists, and seismic analysis and design of engineering structures.

Marianna Polak: punching-shear strengthening techniques for RC slab-column connections, development of constitutive models and nonlinear finite element formulations, non-destructive evaluation of structural members, high-density polyethylene pipes installed by trenchless technology, and interdisciplinary research on characterization of polymeric materials

Mahesh Pandey: risk-based decision support systems for infrastructure management, time-dependent reliability analysis models, risk-based dynamic health monitoring systems, socio-economic cost-benefit analysis for sustainable development, and probabilistic load and strength models.

Khaled Soudki: rehabilitation of corroded reinforced concrete beams with FRP, shear strengthening slab-column connections using FRP, durability of structural members strengthened by FRP sheets, experimental and analytical evaluation of the bond strength of reinforcement in FRP-wrapped concrete beams, and fatigue behaviour of corroded concrete beams strengthened with FRP sheets.

Tarek Hegazy: management of infrastructure networks, decision support for project scheduling and control, time and cost and resource optimization, artificial intelligence applications in construction, and internet-based collaboration in design and construction.

Lei Xu: performance-based building seismic analysis and design, advanced analysis and design for structures under abnormal loading, lightweight steel framed residential building design, analysis and design of cold-formed steel structures, stability analysis, design and optimization of steel framed structures, and floor vibration analysis and design.

John Straube: building enclosure design, moisture physics, and whole-building performance.

Jeffrey West: behaviour of precast structures, durability of precast and post-tensioned concrete structures, use of stainless steel reinforcement, development of high performance self-consolidating concrete, and use of carbon fibre reinforced polymer materials for strengthening of existing structures.

Stanislav Potapenko: modeling the mechanical behaviour of advanced materials, singular integral equations, potential methods in elasticity, mechanics of rubber-like solids, mechanics of thin-walled structures, composite materials, and fluid mechanics

Sriram Narasimhan: risk and reliability analysis of floating structures, control of seismic responses in base-isolated buildings, development of base isolation systems for buildings, algorithms for control and damage detection, and on-line structural health monitoring methods.

Scott Walbridge: small- and large-scale testing of structural elements, stability of structural systems, fatigue analysis of welded structures, fatigue assessment of bridges, probabilistic methods to model deterioration processes, and probabilistic design criteria for structures.

5. Conclusion

Trying to draw some lessons from life or academic experience may prove a rather subjective undertaking as it depends not only on objective factors, but, to a large extent, on such personally-chosen criteria as *survival* and *progress*. In collective endeavors these requirements are dominant at both individual and group levels. We assume for simplification that if the requirements are satisfied for the group, they are implicitly satisfied for the individual. Also assumed is that in an academic group individual members have the necessary intellectual strength and motivation for pursuit of higher learning.

The above observations follow from the analysis of SMD experience, and their general validity should be viewed with caution. However, it seems fair to believe that they are quite apt when considering the future of SMCD.

Group *survival* is influenced by external factors (time, prevailing policies, university orientation, funding sources, etc.), but is critically determined by subjective factors; in addition to its make-up and prerequisite academic strength, a group's existence largely hinges on:

- Strong motivation (conviction that the group adds up to more than its summed parts)
- Clear, realistic objectives
- Firm, properly focused leadership
- Internal cohesion (positive interaction at the operational level)
- Group resilience (will to survive) and adaptability
- Steadfastness in pursuit of objectives

Group *progress* requires unanimous understanding and consistent work on programs and cannot be achieved without:

- Translation of general vision into specific goals

- Choice of correct priorities
- Efficient planning and monitoring of results
- Preservation and promotion of talent (by ensuring true bond and member collegiality)
- Reduction of administrative tasks to minimum necessary

In brief, our main lesson is that group survival and progress are paramount considerations arising out of SMD history. While survival is to a large extent dependent on external factors, progress is mostly an internal product, the essence of which appears to be *making a difference.* Given their essential ingredients, both survival and progress may be achieved with a high probability if membership bond thrives under a far-reaching leadership guided by ambitious, yet realistic goals.

One cannot but hope that, in the spirit of this paper's motto (Buber, 1956), the torch passed from SMD to SMCD will continue to rekindle the sparks of discovery for generations to come.

Acknowledgements

This paper is dedicated to the memory of H.E. Leipholz, J.T. Pindera, T.P. Prasad, J. Roorda and A.N. Sherbourne, our colleagues and friends no longer among us. We gratefully acknowledge the invaluable contributions of all SMD and SMCD members, staff and UW support services.

APPENDIX 1: SM Studies Series

SM Study No. 1
An Introduction to Structural Optimization
Seven Special Lectures at the University of Waterloo
September 23 to December 16, 1968
By: N. Khachaturian, L.A. Schmit, Jr., R.L. Fox, F. Moses, N.C Lind, C.A. Cornell and W. Prager
Editor: M.Z. Cohn

SM Study No. 2
Theory of Structural Design Decisions
C.J. Turkstra
Ph.D. Thesis, 1962

SM Study No. 3
Structural Reliability and Codified Design
Eight Special Lectures presented at the University of Waterloo
October 6 to December 15, 1969
By: Fred Moses, Jack R. Benjamin, G.G. Meyerhof, C.J. Turkstra,
Masanobu Shinozuka, C. Allin Cornell, F. Legerer and H.C. Shah
Editor: N.C. Lind
SM Study No. 4
Stress-Strain Relationships for Concrete and
the Analysis of Structural Concrete Sections
M. Sargin
Ph.D. Thesis, 1971

SM Study No. 5
Computer Aided Engineering
Proceedings of the Symposium held at the University of Waterloo, May 11-13, 1971
Editor: G.M.L. Gladwell

SM Study No. 6
Stability
Fourteen Special Lectures, University of Waterloo
October 1970 to September 1971
By: H. Ziegler, K. Huseyin, A.H. Chilver, M. Sewell, F.K.G. Odqvist, H.H.E. Leipholz,
R. Reissig, S. Nemat-Nasser, V.V. Bolotin, E. Adams, R.H. Plaut
Editor: H.H.E. Leipholz

SM Study No. 7
Applications of Solid Mechanics
Proceedings of the Symposium held at the University of Waterloo, June 26 - 27, 1972
Editors: R.G. Charlwood, University of Waterloo, D.S. Weaver, McMaster University, and B. Tabarrok, University of Toronto

SM Study No. 8
Inelasticity and Non-Linearity in Structural Concrete
International Symposium,
University of Waterloo, January – June 1972
Editor: M.Z. Cohn

SM Study No. 9
Experimental Mechanics In Research and Development
Proceedings of the International Symposium on Experimental Mechanics held at the University of Waterloo, June 12-16, 1972
Editors: J.T. Pindera, H.H.E. Leipholz, D.E. Grierson, University of Waterloo, and F.P.J. Rimrott, CSME – Canadian Society of Mechanical Engineers

SM Study No. 10
Stochastic Problems in Mechanics
Proceedings of the Symposium of Stochastic Problems in Mechanics
University of Waterloo, September 24-26, 1973
Editors: S.T. Ariaratnam, H.H.E. Leipholz

SM Study No. 11
Mechanics in Engineering
Proceedings, First ASCE-EMD Specialty Conference on Mechanics in Engineering
University of Waterloo, May 26-28, 1976
Editors: R.N. Dubey, H.H.E. Leipholz

SM Study No. 12
Continuum Models of Discrete Systems
Proceedings, Second International Symposium on Continuum Models of Discrete Systems
Mont Gabriel, Quebec, June 26 – July 2, 1977
Editor: J.W. Provan, McGill University
SM Study Editor: H.H.E. Leipholz

SM Study No. 13
Advances in Analysis of Geotechnical Instabilities
International Symposium
University of Waterloo, September 1976 – October 1977
Editor: J.C. Thompson

SM Study No. 14
Nonlinear Design of Concrete Structures
CSCE-ASCE-ACI-CEB International Symposium
University of Waterloo, August, 7-9, 1979
Editor: M.Z. Cohn

SM Study No. 15
Continuum Models of Discrete Systems (CMDS3)
Proceedings, Third International Symposium on Continuum Models of Discrete Systems
Freudenstadt, Germany, June 24-30, 1979
Editors: E. Kröner, K.H. Anthony, University of Stuttgart, Germany
SM Study Editor: H.H.E. Leipholz

SM Study No. 16
Fuel-Air Explosions
Proceedings, International Conference on Fuel-Air Explosions
McGill University, Montreal, Canada, November 4-6, 1981
Editors: J.H.S. Lee, C.M. Guirao, McGill University
SM Study Editor: D.E. Grierson
University of Waterloo Press,1982

SM Study No. 17
New Problems in Mechanics of Continua
Proceedings, Third Swedish-Polish Symposium on Mechanics,
Jablonna, Poland, May 10-14, 1982

Editors: O. Brulin, R.K.T Hsieh, Royal Institute of Technology, Sweden
SM Study Editor: D.E. Grierson
University of Waterloo Press, 1983

SM Study No. 18
Studies on Prestressed Concrete
M.Z. Cohn
University of Waterloo, 1988

APPENDIX 2: SM Reports/Papers Series

1. "Application of Limit Design to reinforced Concrete Structures", by M.Z. Cohn, E.F. Burnett, D.E. Grierson, O. Dutt, R. Francis, H.C. Parameswar, S. Talwar (April 1969).
2. "Frame Buckling: An Illustration of the Perturbation Technique", by J. Roorda and A.H. Chilver (May 1969).
3. "A General Formulation or the Stress-Strain Properties of Concrete", by M. Sargin and V.K. Handa (May1969).
4. "Evaluation of the Fatigue Strength of Integrated Tanks for LNG Ships", by D.J. Burns, R.G. Jackson and J.G. Kalbfleisch (May 1969).
5. "A Fundamental Study of Consolidation and the Estimation of Settlement", by B. LeLievre and H.B. Poorooshasb (June 1969).
6. "Concave Programming in Structural Optimization" by G.I.N. Rozvany (June 1969).
7. "Comparison of Finite Element and Unique Limit Analysis Solutions for Certain Reinforced Concrete Slabs", by G.N. McNiece (July 1969).
8. "The Morphology and Growth of Creep Cavities in Alpha-Iron", by A.L. Wingrove and D.M.R. Taplin (July 1969).
9. "Variational Method for Non-Conservative Problems", by R.N. Dubey (July 1969).
10. "Computer Design of Multi-Component Hydrostatic Extrusion Vessels Containing Autofrettaged Components", by R.J. Pick and D.J. Burns (July 1969).
11. "A Theorem on the Limit Analysis of Plates and Shells", by G.I.N. Rozvany (August 1969).
12. "Limit Design for Reinforced Concrete Structures: An Annotated Bibliography", by M.Z. Cohn (August 1969).
13. "On the Studies of Phenomena Related to the Formation of Residual Stress States in Glass Plates", by J.T. Pindera and N.K. Sinha (August 1969).
14. "Inter-granular Creep-Cavitation of Alpha-Brass" by I.J. Spark and D.M.R. Taplin (August 1969).
15. "Further Results on the Equilibrium Method of Limit Design", by M.Z. Cohn and D.E. Grierson (August 1969).
16. "An Elastic-Plastic Finite Element Analysis for Plates with Edge Beams", by G.M. McNeice (August 1969).
17. "Response of Photoelastic Systems", by J.S. Pindera (August 1969).
18. "A Uniqueness Theorem for Non-Linear Plans Frameworks", by O. Dutt and N.C. Lind (September 1969).
19. "Fatigue and Cyclic Thermal Softening of Thermoplastics", by I. Constable, J.G. Williams and D.J. Burns (September 1969).
20. "The Influence of Polycrystal Grain Size upon Creep Ductility", by G.J. Cooks and D.M.R. Taplin (September 1969).
21. "A Stress-Strain Function for the Fatigue of Metals", by K.N. Smith, P. Watson and T.H. Topper (October 1969).
22. "An Automatic Approach to the Analysis of Plastic Frames Under Fixed and Variable Loading", by M.Z. Cohn and D.E. Grierson (October 1969)
23. "Probabilistic Evaluation of Safety Factors", by M.K. Ravindra, A.C. Heaney and N.C. Lind (October 1969)
24. "Studies of Intergranular Creep Cavitation", by G.L. Dunlop, G.J. Cocks, A.L. Wingrove and D.M.R. Taplin (October 1969)
25. "Simple Nonparametric Failure Probability Estimates", by N.C. Lind (October 1969)
26. "Application of Liapunov's Direct Method to the Stability Problem of Rod's Subject to Follower Forces", by H.H.E. Leipholz (December 1969)
27. "Instability of Symmetric Structural Systems with Independent Loading Parameters", by K. Huseyin (December 1969)
28. "Influence of Inertial parameters on the Stability of Non-Conservative Systems", by K. Vepa and J. Roorda (January 1970).
29. "Superplastic Copper Alloys", by D.M.R. Taplin, G.L. Dunlop, S. Sagat and R.H. Johnson (January 1970).
30. "A Lower Bound Approach to the Optimal Design of Concrete Frames and Slabs", by G.I.N. Rozvany and M.Z. Cohn (January 1970).
31. "On the Energy Criterion Applied to Continuous Systems and Based on Liapunov's Method" by H. Leipholz (January 1970)
32. "Variational Finite Element Calculation of the Acoustic Response of a Rectangular Panel", by G.M.L. Gladwell (February 1970)
33. "The Effect of Induced Axial Resistance Due to Geometry Changes in Simple Elastic-Plastic Systems", by N.K. Srivastava and A.N. Sherbourne (February 1970)

34. "On the Estimation of the Stability Boundary of Symmetric Structural Systems", by K. Huseyin (February 1970).
35. "The Application of Liapunov's Direct Method to Stability Problems of Continuous, Nonconservative Systems", by H.H.E. Leipholz (February 1970).
36. "Consistent Partial Safety Factors", by N.C. Lind (February 1970).
37. "The Mechanical Behaviour of a Nickel-free Austenitic Stainless Steel", by V.V.P. Kutumbarao, D.M.R. Taplin and P. Rama Rao (March 1970).
38. "Application of a Generalized Principle of Hamilton to Non-Conservative problems", by H.H.E. Leipholz (March 1970).
39. "Studies of Physical and Mathematical Models of Some Flanged Connections", by Jerzy T. Pindera and Yulun Sze (March 1970).
40. "Elastic Plastic Bending of Circular Plates", by N.K. Srivastava and A.N. Sherbourne (March 1970).
41. "On the Stability of continuous Systems in the First Approximation", by H.H.E. Leipholz (March 1970).
42. "Influence of the Bolt Tensile Stiffness and the Bolt Pretensioning on the Behaviour of the Fact-to-Face Flanged Connections", by Jerzy T. Pindera and Yulun Sze (March 1970).
43. "The Loading-Frequency Relationship in Multiple Eigenvalue Problems", by K. Huseyin and J. Roorda (June 1970)
44. "Thermal Instability in Differentially Heated Inclined Fluid Layers – A Generalization of the Buoyancy Driven Stationary Instability", by T.E. Unny (June 1970)
45. "The Influence of Cyclic Strain Amplitude on the Fatigue Behaviour and Sub-Structure of Pure Iron", by H.A. Raouf, P.P. Benham and A. Plumtree (June 1970).
46. "Prediction of Strain Rate for Constant Strain Rate Drained Triaxial Tests", by A Thurairajah (June 1970).
47. "Experiments on Plastic Limit Behaviour of Shell-Nozzle Junctures Subjected to Nonsymmetric Loading by N.C. Lind and S. Palusamy (June 1970).
48. "The Characteristics and Application of the Clough-Felippa Element in Slab Analysis", by J.C. Jofriet, G.M. McNeice and R. Green (June 1970).
49. "Determination of Dominant Radiation in Polar-scope by Using Babinet Compensator", by J.T. Pindera and N.K. Sinha (June 1970)
50. "Finite Element Analysis of Reinforced Concrete Slabs with Progressive Cracking", by J.C. Jofriet and G.M. McNeice (June 1970).
51. "Limit Analysis of Non Symmetrically Loaded Spherical Shells", by S. Palusamy and N.C. Lind (July 1970)
52. "Elastic-Plastic Bending of Restrained Pin-Ended Circular Plates", by A.N. Sherbourne and N.K. Srivastava (July 1970)
53. "On the Studies of Residual Stresses in Glass Plates, by J.T. Pindera and N.K. Sinha (July 1970)
54. "A Simplified Model for Moderately Thick Plates in Bending", by A.N. Sherbourne and N.K. Srivastava (July 1970)
55. "Nonlinear Optimisation Programmes – Write-up and Performance", by S. Palusamy (July 1970)
56. "Plastic Limit Analysis Using Linear Programming", by D.E. Grierson and G.M.L. Gladwell (July 1970)
57. "The Response of a System with Double-Bilinear-Hysterics to Random Excitation", by B. Sahay and S. Oen (July 1970)
58. "The Role of the Engineer and Technologist in Mechanical Design", by D.C. Ferguson (August 1970)
59. "Development of a 100,000 lb/in ^{2} , 100 cu. In/min Fluid Support Intensifier", by U. Mohaupt and D.J. Burns (September 1970)
60. "Behaviour of Sand During Undrained Triaxial Tests", by A. Thurairajah and B. LeLievre (September, 1970)
61. "On the Stability of the Critical Equilibrium States", by K. Huseyin (November 1970)
62. "Sustained and Cyclic Loading of Concrete Columns", (1970)
63. "On the Sufficiency of the Energy Criterion for the stability of Certain Non-Conservative Systems of the Follower-Load Type", by H. Leipholz (Oct. 1970)
64. "On a Common Theory for the Stability of Self-Adjoint and Non-Self-Adjoint Mechanical Systems" by H. Leipholz (December 1970)
65. "Stability Criteria for Plüger's Rod with Internal and External Damping via Liapunov's Second Method", by H. Leipholz and R. Kapoor (December 1970)
66. Investigation of the Stability of Continuous Non-conservative Systems with Damping by means of Liapunov's Method", by H. Leipholz and R. Kapoor (December 1970)
67. The Plates method and its Application in the Shell Theory", by L. Fischer (December 1970)
68. "An Approximate Method for Stability of Nonconservative Systems", by R.N. Dubey, H. Leipholz, R. Vepa and T.C. Chen (January 1971)
69. "Divergence Instability of Multiple Parameter Circulatory Systems", by K, Huseyin and H. Leipholz (January 1971)
70. "On the Stability of One-Dimensional Continuous Systems with Polygenic Forces", by H. Leipholz and K. Huseyin (January 1971)
71. "Finite Element Analysis of Threaded End Closures of Thick-Walled Vessels", by R.J. Pick and D.J. Burns (January 1971)

72. Optimization of a Structural Code", by M.K. Ravindra and N.C. Lind (January 1971)
73. Towards Practical Application of Structural Reliability Theory", by N.C. Lind and A.G. Davenport (February 1971)
74. "Singular Critical Points in the General Theory of Elastic Stability", by K. Huseyin (March 1971)
75. "On the Uniqueness of Plastic Optimal Design", by M.Z. Cohn, S.R. Parimi and S.K. Ghosh (March 1971)
76. "The Reinforced Concrete Beam-Column Connection", by E.F.P. Burnett and R. Jojoo (May 1971)
77. "The Influence of the Column Load on the Reinforced Concrete Beam-Column Connection", by E.F.P. Burnett and R.J. Trenberth (May 1971
78. "A Unified Approach to the Theory of Plastic Structures", by M.Z. Cohn, S.K. Ghosh and S.R. Parimi (May 1971)
79. "On a Maxwell-Type Solution of Three Dimensional Elasticity", by H. Leipholz (March 1971
80. Random Buckling Behaviour in Axially Loaded Cylindrical Shells with Axisymmetric Imperfections", by J. Roorda and J.S. Hansen (May 1971)
81. "Strength Characteristics of Reinforced Concrete Columns Under Sustained Loading", by J. Hellesland and R. Green (May 1971)
82. "On a Hybrid Type of Galerkin's Equation", by H. Leipholz (May 1971)
83. "The Tensile Properties of a Superplastic Aluminium Bronze", by G.L. Dunlop and D.M.R. Taplin (June 1971)
84. "Multi-Criteria Probabilistic Structural Design", by M.Z. Cohn and S.R. Parimi (June 1971)
85. "Textures and Anisotropic Flow of a Superplastic Aluminium Bronze", by G.L. Dunlop and D.M.R. Taplin (June 1971)
86. "Pattern Loading on Reinforced Concrete Flat Plates", by J.C Jofriet and G.M. McNeice (July 1971.
87. "Equivalent Axisymmetric Imperfections in Axially Compressed Cylindrical Shells", by J. Roorda (June 1971)
88. "Elastic-Plastic Deformation Analysis Using Linear Programming", by D.E. Grierson (July 1971)
89. "The Design of Structural Design Norms", by N.C. Lind (August 1971)
90. "On the Dynamic Stability of Fluid-Conveying Pipes", by D.S. Weaver and T.E. Unny (August 1971)
91. "The Elastic Stability of Two-Parameter Nonconservative Systems", by K. Huseyin and R.H. Plaut (August 1971)
92. "Superplasticity and Cavitation in Alpha-Beta Brass", by S. Sagat, P. Blenkinsop and D.M.R. Taplin (September 1971)
93. "A Metallographic Study of Superplasticity in a Micrograin Aluminium Bronze", by G.L. Dunlop and D.M.R. Taplin (September 1971)
94. "Potential Flow of a Vortex Row with Statistically Varying Spacings", by F.J. Legerer and U. Lemmin (September 1971)
95. "Influence of the Width of Loading Plate on the Rotation Capacity of Reinforced Concrete members", by C.S. Chandrasekhar and H.A. Falkner (October 1971)
96. "A Rotary Coupling for Pressures up to 100,000 psi", by F.M. Smith and U.H. Mohaupt (October 1971)
97. "The Multiple-Parameter Perturbation Technique for the Analysis of Non-Linear Systems", by K. Huseyin (November 1971)
98. "Optimal Design of Plastic Structures for Fixed and Shake-Down Loadings", by M.Z. Cohn and S.R. Parimi (November 1971)
99. "Equilibrium (Serviceability) Methods of Limit Design for Concrete Frames", by M.Z. Cohn (November 1971)
100. "The Flexural Ductility of Reinforced Concrete Sections", M.Z. Cohn and S.K. Ghosh (November 1971)
101. "Some Re-Interpretations of Structural Analysis", by G.M.L. Gladwell (January 1972)
102. "Stability of Hauger and Pfluger Systems with Kelvin Model and External Damping", by H.H.E. Leipholz and Ravi Kapoor (January 1972)
103. "A Note on Effect of Stiffeners in Light Gage Members", by N.C. Lind (January 1972)
104. "Qualitative Stability Theory of Completely Supported Roads Subjected to Follower Forces", by H.H.E. Leipholz and R.N. Dubey (January 1972)
105. On the Calculation of Flutter Loads by Means of a Variational Technique", by H.H. E. Leipholz (February 1972)
106. "Finite Element Analysis of the Axisymmetric Vibrations of Cylinders", by G.M.L. Gladwell and U.C. Tahbildar (February 1972)
107. "On the Analysis of Elgenvalue Curves of Roads Subjected to Conservative and Non-Conservative Loads", by H.H.E. Leipholz (February 1972)
108. "Mechanical Behaviour of Polycrystals at Elevated Temperatures", by D.M.R. Taplin, P. Rama Rao and V.V.P.K. Rao (March 1972)
109. "Multi-Parameter Optimal Design of Plates and Shells", by Z. Mroz (March 1972)
110. "Influence of Kelvin Model Damping in Flutter-Divergence Transitional Polygenic Systems", by H.H.E. Leipholz and Ravi Kapoor (March 1972)
111. "Structural Analysis for Idealized Nonlinear Material Behaviour", by Graham M.L. Gladwell and Donald E. Grierson (April 1972)
112. "On Extremum Properties of the Generalized Rayleigh Quotient Associated with Flutter Instability", by K. Huseyin and R. Plaut (September 1972)

113. "an Invariant Second Moment Reliability Format", by N.C. Lind (November 1972)
114. "On the Solution of Plane Stress Problems Using Complex Potentials and Photoelastic Data", by H.A. Atta and J.C. Thompson (December 1972)
115. "Bending by Beginners", by E.F.P. Burnett (February 1973)
116. "Some Aspects of Office Design Live Load", by W.W.C. Siu and N.C. Lind (February 1973)
117. "Second-Order Collapse Load Analysis: a LP Approach", by S. Baset, D.E. Grierson and N.C. Lind (March 1973)
118. "Analysis of Plastic Frames Allowing for the Effect of Axial forces", by M.Z. Cohn and T. Rafay (March 1973)
119. "An Exact and Invariant First-Order Reliability Format", by A.M. Hasofer and N.C. Lind (May 1973)
120. "Adaptive Control of Design Codes", by G. Schorn and N.C. Lind (May 1973)
121. "On the Method of Trefftz in the Light of a Generalized Variational Principle", by H. Leipholz (June 1973)
122. "Effect of Grain Size on the Tensile Properties of a Cr-Mn-N Austentific Strainless Steel in the Temperature Range 25 to 1000 degrees C", by V.V. Ktumbarao, P. Rama Rao and D.M. R. Taplin (October 1973)
123. "Floor Beams in Orthotropic Bridges", by K.N. Smith and J. Mastofrancesco (October 1973)
124. "Design of Reinforced Concrete Structures for Strength and Deformability", by Mir M. Ali and Donald E. Grierson (January 1974)
125. "On a Modified Rayleigh"s Quotient for a Certain Nonconservative Elgenvalve Problem", by H.H. E. Leipholz (January 1974)
126. "Shear Strength of Reinforced Concrete Beams with Short Shear Spans", by S.M. Fereig and K.N. Smith (February 1974)
127. "Inelastic Behaviour of Prestressed Concrete Structural Members", by M. Balabanian, S.K. Ghosh and M.Z. Cohn (May 1974)
128. "A Formulation of Probabilistic Design", by N.C. Lind (April 1974)
129. "On Conservative Elastic Systems of the First and Second Kind", by H.H.E. Leipholz (June 1974)
130. "The Post-Yield Strength of R.C. Flexural Sections", by E.F.P. Burnett and S.K. Ghosh (June 1974)
131. "Optimal Solutions in Probabilistic Structural Design", Part 1: Theory; Part 11: Applications, by S.R. Parimi and M.Z. Cohn (June 1974)
132. "Some Remarks on Liapunov Stability of Elastic Dynamical Systems", by H.H.E. Leipholz (July 1974)
133. "A Linear Programming Approach to the Problem of Moments", by W.W.C. Siu, S.S. Sengupta and N.C. Lind (August 1974)
134. "On Destabilizing Parameters, the Degree of Stability of Mechanical Systems, and General Stability Criteria", by H.H.E. Leipholz (February 1975)
135. "Fatigue Studies of O.F.H.C. Copper and a Copper Dispersion Alloy at 300-750 degrees C", by G.J. Cocks and D.M.R. Taplin (May 1975)
136. "On Extension of Steklov's Inequality and a Lower Bound Theorem for Pflüger's Rod" by H.H.E. Leipholz (December 1975)
137. "Mathematical Programming Methods for Deformation Analysis At Plastic Collapse", by G. Maier, D.E Grierson, M.J. Best (March 1976)
138. "Four Papers on Catalogue Optimization", by N.C. Lind et al (August 1976)
139. "Plastic Analysis Under Combined Stresses", by Donald E. Grierson, M.ASCE, and Saleh B. Abdel-Baset (August 1976)
140. "Morphology and Fracture of Bone", by K.R. Piekarski (September 1976)
141. "On the Application of the Energy Method to the Stability Problem of Nonconservative Autonomous and Nonautonmous Systems", by H.H.E. Leipholz (September, 1976)
142. "A General Computer Program For Plastic Analysis" by D.E. Grierson and S.B. Abdel-Baset (July 1977)
143. "Local Buckling of Thin Walled Channels" by K.R. Venkataramaiah and J. Roorda (November 1977)
144. "Fracture of a Petrochemical Furnace Tube Steel at High Temperature" by G.L. Dunlop, R.J. Twigg and D.N.R. Taplin (November 1977)
145. "On a Variational Principle For Beck's Rod", by H.H.E. Leipholz (January 1978)
146. "On an Extension of Hamilton's Variational Principle to Nonconservative Systems Which are Conservative in a Higher Sense", by H.H.E. Leipholz (January 1978)
147. "Fracture Research in Canada" by D.J. Burns and D.M.R. Taplin (May 1978)
148. "Effective Width of Stiffened Steel Plate Components" by J. Roorda and K.R. Venkataramaiah (May 1978)
149. Optimization of Finite element Studies of Stress Concentration Regions Using Asymptotic Analysis" by D.D. Curtis and J.C. Thompson (September 1978)
150. "Mathematical Programming and Nonlinear Finite Element Analysis" by D.E. Grierson, A. Franchi, O. DeDonato, and L. Corradi (October 1978)
151. "Effective Width of Stiffened Cold-Formed Steel Plates" by J. Roorda and K.R. Venkataramaiah (October 1978)
152. "Pressurised Ring Stiffened Shells: A Model Study" by John Roorda (November 1978)
153. "Non-Stationary Narrow-Band Response and First Passage Probability", by Steen Krenk, Risö National Laboratory, Roskilde, Denmark (December 1978)

154. "On the Elastic Constants of Plane Orthotropic Elasticity" by Steen Krenk, Risö National Laboratory, Roskilde, Denmark (December 1978)
155. "Computer Analysis of Elastic-Plastic Structures" by M.Z. Cohn and A. Franchi (January 1979)
156. "Bifurcation in Elastic-Plastic Plates" by R.N. Dubey (April 1979)
157. "An Elastic-Plastic Analysis Computer System" by A. Franchi, D.E. Grierson, M.Z. Cohn (August 1979)
158. "Plastic Design Under Combined Stresses", by Donald E. Grierson and Ahmed A. Aly (September 1979)
159. "On the Use of the Hamiltonian for an Evaluation of the Stability of Elastic Systems Subjected to Follower Forces" by H.H.E. Leipholz (July 1980)
160. "On Topological Aspects of Liapunov Stability of Continuous Systems" by H.H.E. Leipholz" (July 1980)
161. "Plastic Design Under Multiple Loads" by Donald E. Grierson, M.ASCE and Ahmed A. Aly (August 1980)
162. "On a Generalization of the Lower Bound Theorem for Elastic Rods and Plates Subjected to Compressive Follower Forces" by H.H.E. Leipholz (September 1980)
163. "Bayesian Approach to Prototype Testing" by P. Hauge Madsenand Niels C. Lind (January 1981)
164. "Probabilistic Models for Prototype Testing", by Mircea Grigoriu M.ASCE and Niels C. Lind (May 1981)
165. "Synthesis Under Service and Ultimate Performance Constraints" by D.E. Grierson and L.A. Schmit Jr. (July 1981)
166. "Active Vibration Control of a Simple Beam" by D. Camotim and J. Roorda (August 1981)
167. "The High Temperature Fatigue and Tensile Fracture of Cu-Cr Based Alloys", by N.Y. Tang and D.M.R. Taplin
168. "Nonlinear Flexural Response of Partially Prestressed Concrete Sections" by M.Z Cohn and M. Bartlett (October 1981)
169. "The Analysis and Prediction of Lateral Instability in Highly Stressed, Near-Surface Rock Strata", by J. Roorda, J.C. Thompson and O.L. White (October 1981)
170. "A Review of the Role of Stress State, Environment and Section Size on Creep Deformation and Fracture", by M.C. Pandey, B.F. Dyson and D.M.R. Taplin (October 1981)
171. "A New Method of Fast Probability Integration", by X. Chen and N.C. Lind (June 1982)
172. "Synthesis of Frameworks Under Multilevel Performance Constraints" by Donald E. Grierson and Thomas C.W. Chiu (July 1982)
173. "Modelling of Uncertainty in Discrete Dynamical Systems" by N.C. Lind (August 1982)
174. "Dynamics of a Mobile Tank Partially Filled with Liquid: Equations of Motion and Their Linearization", by Aleksander Kornecki (September 1982)
175. "Inelastic Behavior of Continuous Prestressed Concrete Beams" by M.Z. Cohn, F. ASCE and Y. Frostig (November 1982)
176. "The Power Method in Finite Element Analysis of Plastic Bifurcation Plate Problems", by H. El-Ghazaly and A.N. Sherbourne (1983)
177. "Structural Design Using Intelligent Structural Analysis" by Don Grierson (January 1983)
178. "Inelastic Interactive Distortional Buckling of W-Shape Steel Beams", by H.A. El-Ghazaly A.N. Sherbourne and R.N. Dubey (1983)
179. "Optimal Synthesis of Steel Frameworks Using Standard Sections" by D.E. Grierson and W.H. Lee (October 1983)
180. "Degenaly, Hopf Fifurcation", by S.T. Ariaratnam and N. Sri Namachchivaya (September 1983)
181. "Optimization of Structural Concrete Beams", by M.Z. Cohn and A.J. MacRae (September 1983)
182. "The Inverse Problem for the Vibrating Beam", by G.M.L. Gladwell (September 1983)
183. "External Disturbances in Transient One-Dimensional Diffusion", by E. Rosenblueth (September 1983)
184. IEM Paper No. 1, "Theory of Elastic and Photoelastic Isodynes", by Jerzy-Tadeusz Pindera and Bogdan Roman Krasnowski (October 1983)
185. IEM Paper No. 2, "Analysis of Models of Stress in the Regions of Crack, Using Isodyne Photoelasticity", by J.T. Pindera, B.R. Krasnowski and M.J. Pindera (October 1983)
186. "Partial Prestressing: From Theory to Practice, Introductory Report", by M.Z. Cohn (October 1983)
187. "On the Inverse Problem of the Vibrating String or Road", by G.M.L. Gladwell and J.A. Gbadeyan (November 1983)
188. "IEM Paper No. 3 "Basic Theories and Experimental Methods of Gradient Photoelasticity", by J.T. Pindera, F.W. Hecker and B.R. Krasnowski (January 1984)
189. "Computer-Automated Synthesis of Building Frameworks", by Donald E. Grierson and Gordon E. Cameron (February 1984)
190. IEM Paper No. 4, "The Interplay and Use of Experimental and Mathematical Models in Research", by Peter G. Glockner (August 1984)
191. "IEM Paper No. 5, "The Impact of Research on Socio-Economic Development", by Karl Hans Laermann (August 1984)
192. "Discussion of Four Theories on the Penetration of Metallic Targets" by K. Nixdorff (September 1984)
193. "On the Effect of Residual Stresses in the Plastic Buckling of Columns – a Model Study" by Dinar Camotim and John Roorda (October 1984)
194. "Bifurcation of Elastic-Plastic Solids with Residual Stresses" by D. Camotim and J. Roorda (December 1984)

195. "Buckling Behaviour of Ring-Stiffened Cylinders: Experimental Study", by S.S. Seleim, J. Roorda (January 1985)
196. "The Stability of Cylindrical Air-Supported Structures", by R. Maaskant and J. Roorda (March 1985)
197. "Theoretical and Experimental Results on the Post-Buckling of Ring-Stiffened Cylinders" by S.S Seleim and J. Roorda (May 1985)
198. "On the Modified S-N Curve for Metal Fatigue Prediction and its Experimental Verification", by H.H.E. Leipholz (May 1985)
199. "Analysis of Flexible Frames by Energy Search", H.A. El-Ghazaly and G.R. Monforton (November 1985)

APPENDIX 3: SM Technical Notes/Reports Series

1. "Yield Surfaces", by Antoni Sawczuk (March 1971)
2. "Optimal Limit Design for Concrete Structures", by M.Z. Cohn (April 1971)
3. "An experience in Equilibrium and Stability", by J. Roorda (May 1971)
4. "Cyclic Deformation and Fatigue Behaviour of Axial and Flexural Members – a Method of Simulation and Correlation", by H.R. Jhansale and T.H. Topper (June 1971)
5. "Utilization of Cold Work in Light Gage Steel", by N.C. Lind and D.K. Shroff (June 1971)
6. "A Review of the Effective Width Formula", by N.C. Lind, M.K. Ravindra and J. Power (June 1971)
7. "Optimum Edge Stiffeners for Thin-Walled Structural Elements", by K.R. Venkataramaiah (July 1971)
8. "How Safe are the Eccentrically Loaded Thin-Walled Steel Struts", by K.R. Venkataramaiah (August 1971)
9. "Ultimate Strength of Eccentrically Loaded Thin-Walled Open Channel Columns", by K.R. Venkataramaiah (August 1971)
10. "Fatigue and Creep Failure of Alpha-Iron at 450-700 degrees C", by H.J. Westwood and D.M.R. Taplin (September 1971)
11. "Creep and Fatigue Fracture Behaviour of Inconel Alloy X-750", by P.K. Venkiteswaran, D.C. Ferguson and D.M.R. Taplin (October 19710
12. "The Influence of Grain Size and Dispersion on the Creep Ductility of Copper Bass Alloys", by R.G. Fleck and D.M.R. Taplin (October 1971)
13. "Curvature of Cracked Reinforced Concrete Sections", by S.K. Ghosh and C.S. Chandrasekhar (November 1971)
14. "Effects of Temperature and Deformation Rate on Cyclic Strength and Fracture of Low-Carbon Steel", by H. Abdel-Raouf, A. Plumtree and T.H. Topper (November 1971)
15. "Compression in thin-Walled Members", by K.R. Venkataramaiah and N.C. Lind (January 1972)
16. "The Analysis and Synthesis of Resonators", by G.M.L. Gladwell (February 1972)
17. "Some Examples of Code Calibration", by N.C. Lind, M.K. Ravindra and W. Siu (February 1972)
18. "The Algebraic Elgenvalue Problem – A Set of Fortran Subroutines", by G.M.L. Gladwell and U.C. Tahbildar (March 1972)
19. "Safety Level Decisions", by N.C. Lind and E. Basier (February 1972)
20. "On Simplified Theories of Cyclic Plasticity", by Z. Mroz and N.C Lind (June 1972)
21. "Post-Buckling Behaviour of Thin Compression Elements with Edge Stiffeners", by K.R. Venkataramaiah (July 1972)
22. "Structural Reliability and the Invariance Problem", by Ove Ditlevsen (March 1973)
23. "A computer Programme for the Non-Linear Analysis of Reinforced Concrete Sections", by M. Sargin, S.K. Ghosh and M.Z. Cohn (March 1973)
24. "Deformational Analysis of Reinforced Concrete Structure-Problems and Prospects", by C.S. Chandrasekhar and S.K. Ghosh (March 1973)
25. "The Algebraic Elgenvalue Problem: A Commentary on Some Computer Programs", by G.M.L. Gladwell (May 1973)
26. "The Computer Programme DAPS for the Design and Analysis of Plastic Structures", by S.R Parimi, S.K. Ghosh and M.Z. Cohn (June 1973)
27. "Optimization of Economic Activities Under Public Regulation", by Niels C. Lind (April 1974)
28. "Stochastic Models for Fatigue Failure of Materials", by S.K. Srinivasan (June 74)
29. "Some Reinterpretations of Structural Analysis" by G.M.L. Gladwell (December 1975)
30. "On Stochastic Load Combination", by Henrik O. Madsen (October 1978)
31. "Khacian's New Linear Programming Algorithm by Richard J. Caron (August 1980)

APPENDIX 4: SM Lecture/Seminar Series

Six Lectures on Stability of Elastic Systems
H.H.E. Leipholz
1971

Theory of Codified Structural Design
N.C. Lind
A set of invited lectures, Polish Academy of Sciences, Warsaw, Poland
June 5-15, 1972

Mathematical Models of Inelastic Material Behaviour
Z. Mroz
Institute of Fundamental Technical Research,Warsaw, Poland
1973

Stochastic Point Processes
S.K. Srinivasan
Indian Institute of Technology,Madras, India
1973

Design in Cold Formed Steel
R.M. Schuster (Editor)
1974

Newmark's Numerical Method
N.C. Lind
1975

Six Lectures on Variational Principles in Structural Engineering
H.H.E. Leipholz
1978

Buckling of Elastic Structures
J. Roorda
1980

A Brief Course on the Theory of Buckling
L.M. Kachanov
University of Delaware
H.H.E. Leipholz (Editor)
1981

Buckling of Thin-Walled Rods
L.M. Kachanov
Boston University, Boston, Ma.
H.H.E. Leipholz (Editor)
1983

APPENDIX 5: SM Texts, Manuals, Proceedings, and Other Publications

SM Text No. G1
Analysis and Design of Inelastic Structures
Volume 2: Problems, 1972
M. Z. Cohn

Cold Formed Steel Design Manual
R.M. Schuster and N.C. Lind
1975

Fracture 1977
Proceedings, 4th International Conference on Fracture
Waterloo, Ont., June 1977
D. M. R. Taplin (Editor)

Engineering Plasticity by Mathematical Programming
Proceedings, NATO Advanced Study Institute
Waterloo, Ont., August 2-12, 1977
M.Z. Cohn, G. Maier and D.E. Grierson (Editors)
Pergamon Press, New York, Toronto, 1979

B. M. Fraeijs de Veubeke Memorial Volume: Selected Papers
SM Archives Special Publication

M. Geradin (Editor)
1980

STRUPL 1: User's Manual
M.Z. Cohn, F. Erbatur and A. Franchi
1982

Micromechanisms of Plasticity and Fracture
M.H. Lewis, Warwick University, England and
D.M.R. Taplin, Trinity College, Dublin, Ireland (Editors)
University of Waterloo Press, Waterloo, Ont.,1983

Nonlinearity and Continuity in Prestressed Concrete
Preliminary Publication (4 Volumes), International Symposium
ACI, ASCE, CEB, CPCI, CSCE, FIP, IABSE, PCI, SMD
Waterloo, Ont., July 4-6, 1983
M.Z. Cohn (Editor)

Contact Mechanics and Wear of Rail and Wheel Systems
Proceedings, First International Symposium
University of British Columbia, Vancouver, B.C., July 6-9, 1982
J. Kalousek, R.V. Dukkipati and G.M.L. Gladwell (Editors)
University of Waterloo Press, 1983

Partial Prestressing: From Theory to Practice
Proceedings, NATO Advanced Research Workshop (2 Volumes)
Paris, France, June 18-22,1984
M.Z.Cohn (Editor)
Martinus Nijhoff Publishers, Dordrecht, The Netherlands,1986

Contact Mechanics and Wear of Rail and Wheel Systems
Proceedings, Second International Symposium
University of Rhode Island, Kingston, R.I., July 8-11.1986
G.M.L. Gladwell, H. Ghonem and J. Kalousek (Editors)
University of Waterloo Press, 1987

*APPENDIX 6: SM Workshops, Conferences, and Symposia **

Colloquium on Limit Design for Structural Concrete
ACI, ASCE, SMD Colloquium (see Appendix 2, No.1)
September 6-8, 1967

Computer-Aided Engineering
SMD Symposium (see Appendix 1, No.5)
May 11-13, 1971

Applications of Solid Mechanics
SMD Symposium (see Appendix 1, No 7)
June 26, 27, 1972

Experimental Mechanics in Research and Development
International Symposium (see Appendix 1, No.9)
June 12-14, 1972

Stochastic Problems in Mechanics
International Symposium (see Appendix 1, No.10)
September 24-26, 1973

Mechanics in Engineering
First ASCE, EMD Specialty Conference (see Appendix 1, No.11)
May 26-28, 1976

Fracture 1977
Fourth International Conference (see Appendix 5, No.3)
June 1977

Continuum Models of Discrete Systems (CMDS 2)
Second International Symposium (see Appendix 1, No.12)
June 28-July 2, 1977

Engineering Plasticity by Mathematical Programming
NATO Advanced Study Institute (see Appendix 5, No.4)
August 2-12, 1977

Nonlinear Design of Concrete Structures
ASCE, ACI, CEB, CSCE International Symposium (see Appendix 1, No.14)
August 7-9, 1979

Continuum Models of Discrete Systems (CMDS 3)*
Third International Symposium, Freudenstadt, Germany (see Appendix 1,No.15)
June 24-30, 1979

Fuel-Air Explosions *
International Conference, Montreal, Que. (see Appendix 1, No.16)
November 4-6, 1981

New Problems in Mechanics of Continua *
Third Polish-Swedish Symposium, Jablonna, Poland (see Appendix 1, No.17)
May 10-14, 1982

Contact Mechanics and Wear of Rail and Wheel Systems (I) *
International Symposium, Vancouver, B.C. (see Appendix 5, No.9)
July 6-9, 1982

Nonlinearity and Continuity in Prestressed Concrete
ACI, ASCE, CEB, CPCI, CSCE, FIP, IABSE, PCI, SMD
International Symposium (see Appendix 5, No.8)
July 4-6, 1983

Partial Prestressing: From Theory to Practice *
NATO Advanced Research Workshop, Paris, France (see Appendix 5, No.10)
June 18-22, 1984

Contact Mechanics and Wear of Rail and Wheel Systems (II) *
International Symposium, Kingston, R.I. (see Appendix 5, No.11)
July 8-11, 1986

References

Buber M. (1956) “Teaching and Deed”, in *The Writings of Martin Buber*, W. Herberg (Ed.), Meridian Books, NY, p. 324.

Cohn M.Z. (1972) *Analysis and Design of Inelastic Structures*, SM Text G1, Vol. 2, 521 pp.

Cohn M.Z., Burnett E.F., Grierson D.E., Dutt O., Francis R., Parameswar H.C. and Talwar S. (1969) “Application of Limit Design to Reinforced Concrete Structures”, SM Report (Paper) No. 1, 56 pp.

Petch H.E. (1973) “Policy Issues for Canadian Science and Technology”, in *Experimental Mechanics in Research and Development*, J.T. Pindera et al. (Eds.), SM Study No. 9, pp. 33−42.

***** NOTE: Listed conferences were held at Waterloo, or had editorial/publishing SMD involvement when star-marked *.