

Lehigh University Lehigh Preserve

Fritz Laboratory Reports

Civil and Environmental Engineering

1955

The formation of column research council and its program. Proceedings of the fifth technical session

Lynn Beedle

Follow this and additional works at: <http://preserve.lehigh.edu/engr-civil-environmental-fritz-lab-reports>

Recommended Citation

Beedle, Lynn, "The formation of column research council and its program. Proceedings of the fifth technical session" (1955). *Fritz Laboratory Reports*. Paper 1474.

<http://preserve.lehigh.edu/engr-civil-environmental-fritz-lab-reports/1474>

This Technical Report is brought to you for free and open access by the Civil and Environmental Engineering at Lehigh Preserve. It has been accepted for inclusion in Fritz Laboratory Reports by an authorized administrator of Lehigh Preserve. For more information, please contact preserve@lehigh.edu.

TABLE OF CONTENTS

	<u>Page</u>
I. The Formation of the Column Research Council and Its Program Lynn S. Beedle	1
II. Reports from Various Research Committee Chairmen on Work of the Council	
Research Committee A (Materials) Bruce G. Johnston, Ch.	22
Research Committee C (Local Buckling) George Winter, Ch.	24
Research Committee D (Columns in Frames) N. J. Hoff, Ch.	26
Research Committee E (Lateral Buckling) Harry Hill, Ch.	27
Research Committee F (Dynamics) N. J. Hoff, Ch.	32
Committee on Recommended Practice J. Jones, Ch.	33
III. A Re-Examination of the Program of the Council	
E. L. Erickson	34
Neil Van Eenam	35
H. H. Bleich	36

THE FORMATION OF COLUMN RESEARCH COUNCIL
AND ITS PROGRAM

by
Lynn S. Beedle

I. I N T R O D U C T I O N

The chairman of the Council has asked me to discuss three aspects of the formation of C.R.C. and of its program:

- (1) Why was the C.R.C. formed?
- (2) How was the program set up -- what were the important problems?
- (3) How were the Committees set up and what were their assignments?

As is customary in these sessions of the annual meeting, emphasis is to be given to the contribution of research projects to problems facing the designer.

It is understood that this discussion will be followed by a description of the work of the various committees and, finally, by a review of the information that is still needed by designing engineers.

As a first comment, a major portion of the work of forming the Council and setting up its program was done before the writer was connected with it as Secretary. Consequently, most of the following remarks are based upon:

- (1) a poring over the minutes and letters, and
- (2) contact with committees after 1947.

This talk might well have been titled, "A Trip Through the CRC Files". And in that respect acknowledgement is due:

- (1) Bruce Johnston for maintaining such excellent records,
- (2) The able stenotypist of the 1944 organizing meeting and 1945 Annual Meeting.
- (3) Bulletin No.1 of the Council. (1)

A few general impressions are in order -- impressions obtained on the aforementioned "trip". They are noted because they bear upon the "practicality" of the Council's program:

- (1) The Council was started by practicing engineers. The need grew out of requests from industry that were brought forcibly to the attention of practicing engineers. University professors, while they participated in some of the organizing, did not initiate formation of the Council.

(1) B.G. Johnston & Project Supervisor, "A Survey of Progress" CRC Bulletin No.1, January 1952.

- (2) The need for CRC was quite generally agreed upon. While Mr. F.H. Frankland, Mr. Jonathan Jones, and Mr. Shortridge Hardesty were most instrumental in suggesting and setting up the CRC, there was no hesitancy on the part of other engineers to participate and assist.
- (3) The work of organizing and setting up the first work moved very rapidly particularly in 1946, 1947, 1948. 100% attendance at committee meetings was not unusual.
- (4) Only part of the CRC program and purpose is embraced by the word, "Research". In its early days, by far the most important aspect was considered to be putting into practice what was already known.

With this background, the formation of the Council and its committees will now be considered.

II. F O R M A T I O N O F C O L U M N R E S E A R C H C O U N C I L

Why was the Council formed? Who formed it? What organization plan was developed?

2.1. CHRONOLOGY

Let's start with an examination of the chronology of CRC (Fig.1). It constitutes somewhat of an outline of this talk, covering:

- (1) The Need
- (2) Organizational Development
- (3) The Program
- (4) Assignments

Figure 1 is largely self-explanatory. The start of a continuous thread of activity was in 1939 when Mr. Jonathan Jones forwarded a request to the ASCE that it look into the problem of column formulas for high-strength steels. As the ASCE took up this problem, it became evident that a national agency was needed. The following is quoted from a December 8, 1941, letter of Mr. Jonathan Jones:

"Some years ago the American Railway Engineering Association adopted a formula for steel columns, based upon research which had been performed by an ASCE Committee. This took the form of a parabolic formula. Soon thereafter A.I.S.C. brought its Specification for Buildings as nearly as practicable into line with the various new formulas and methods of the A.R.E.A. Specifications, and among other things it also adopted a parabolic column formula, increasing the allowable unit stresses somewhat, corresponding to the fact that its basic tensile stress was 20,000 instead of the A.R.E.A. 18,000.

"Since that time the A.I.S.C. formula has been the subject of considerable discussion. The New York City Building Department, although willing to accept most of the new A.I.S.C. Specification, seemed disposed to go off into a huddle by itself and do some independent thinking and arrive at a different column formula. American Standards Association appointed a Committee on a Standard Specification for Steel for Buildings, and that committee seemed willing to accept most of the A.I.S.C. Specification, but again desired to write a column formula that would suit the individual members of that committee somewhat better. In Los Angeles a specification writing body copied the A.I.S.C. FORMULA but put a correction factor on it to reduce the allowable stress on long columns.

"With all this going on, I hated to see the A.I.S.C. independently or with A.S.C.E., embarking on a lot of additional column research, out of which conceivably would arise new or modified column formulas, which then would either have to be sold to all the other specification writing bodies, or quite possibly could not be sold to them at any price.

"Therefore I urged and do urge that it is a national necessity that as many as possible of the bodies who are interested in writing formulas for steel columns get together in some kind of a central group and carry on the research and analyze the results in a way that will be satisfactory to all. In that way, without stifling independence of thought, we may be able to crystallize ideas so that there will be an American idea about columns, which certainly there is not at the present time."

Concerning the suggested formation of Column Research Council, Mr. F.H. Frankland wrote as follows on October 15, 1943 (quoted in part):

"There are many different specifications required to meet many situations and uses, and it would seem logical, therefore, that all such specifications should originate in one acceptable body of test and research data as to ultimate capacity, and be followed by a general agreement, legislative and otherwise, as to the several factors of safety against ultimate capacity required under various conditions. In order to bring about a general agreement and acceptance of such rules or requirements, as may eventually be found desirable, it is therefore suggested that a Column Research Council be organized, under Engineering Foundation."

"I am only one of a number who are convinced that a satisfactory resolution of the variable and conflicting ideas regarding compression members that

"have persisted for generations can be achieved only by the formation of such a body as the proposed Council. As I see it, the leaders in the various branches of the engineering profession affected have the responsibility to bring order out of chaos."

As Bruce Johnston effectively stated in his letter of October 27, 1944,

"We should not lose sight of the fact that the proposed council was initiated by Messrs. Frankland, Jones, and Hardesty, with the main purpose of integrating the activity of various column specification writing bodies throughout the country and reducing the variance between the many different specifications on columns as well as guide the writing of new specifications on new materials such as the low alloy structural steels. It was rightly thought that this was too big a job to be undertaken by our A.S.C.E. Committee on Design of Structural Members, which is interested primarily in analysis and research."

In addition, the development of the light alloys was in progress, and although it was not directly related to formation of the Council, research on aircraft structures was proceeding rapidly.

At about this same time, the AISC column formula was being revised, following which revisions of the New York building code were in progress.

All of these developments pointed to a need for expanding the representation of the old ASCE Committee on Design of Structural Members. Sponsorship by Engineering Foundation was thought to give a more nationwide coverage.

"The Program" was set up mainly through four activities as shown in Fig. 1. Further mention of these will be made later.

The first broad "Assignments" were given to the main committees at the time of the first Annual Meeting (1945), to Committees A to D in 1946, 1947, and to Committees E.F.G in 1949,1950.

2.2. PURPOSES

From the discussion thus far, the purposes of the Council may be formulated. This has been done in outline form in Fig. 2, the "official" purposes being reproduced from the By-Laws in Fig. 3.

The two important requirements were:

- (1) Remove confusion and lack of harmony in design procedures, and
- (2) Fill existing gaps in knowledge.

2.3. ORGANIZATION

An organization to carry out the purposes just discussed was finally evolved as shown in Fig. 4:

- (1) A Council was set up of representatives of the various specification-writing groups.
- (2) An Executive Committee -- to transact the business of the Council and to organize and give direction to the Committees.
- (3) A Technical Board -- later deleted but originally formed to organize the committees.

The other committees are also shown, the letter designating the various Research Committees. The Steering Committee, having served its organizing function, was abolished in 1950; thereafter the Research Committees reported directly to the Executive Committee.

Fig. 5 shows the further detail of the CRC organization as it pertains to just three groups: Research Committees, Recommended Practice, and the Category Groups. At the first Annual Meeting, considerable emphasis was given to the importance of this latter group. One of the first plans was to organize these groups as committees set up by a Membership sub-committee of the Executive Committee. Later, it was decided that other means could be used to see that:

- (1) The needs of specification-writing groups would be defined to the Council, and,
- (2) Council recommendations would find ready reception with the parent organizations.

It is noteworthy that there is little or no correlation between the different Research Committees (A-F) and the "Category Groups". One is set up to handle a research project or to give technical evaluation. The other represents a designer with an interest in a particular kind of structure. A basic Council aim is to join the two.

As yet we have not seen the assignments to research committees. However, these assignments came as an outgrowth of setting up the Council's program -- and this topic will be considered next.

III. P R O G R A M O F C O L U M N R E S E A R C H C O U N C I L

What was the basis for setting up the program of work for the Council? Fig. 6 shows how the program developed.

3.1. FIRST WORK

There were three aspects to the preliminary work of the Council:

- (1) Survey of Current Problems
- (2) Literature Survey and Evaluation
- (3) Survey of Current Research

Project recommendations from the various committees followed or were concurrent with the above three undertakings and generally were based on a study of the results.

A detailed statement of the first questionnaire is contained in Fig.7. It is significant that the first effort of the Council was to determine those unsolved problems that practicing engineers thought were important. This was then followed by the literature survey and recommendations for projects.

3.2. DEVELOPING PROGRAMS

How did these first studies affect the program?

The survey of current problems probably had the most profound influence as it oriented the committee's thinking. The literature survey (Bleich) provided an up-to-date evaluation of problems and of methods of analysis. The current research survey provided data to Dr. Bleich and to the committees and first investigators.

More specifically, the influence of the first questionnaire survey on the programs of the council is shown in Fig. 8. This one-page listing is an abstract of a larger report that has been issued to the Council⁽²⁾ and is also contained in the Council's PROSPECTUS⁽³⁾. Only the most important or the most frequently suggested problems are listed.

This tabulation lists the problems, indicates the action suggested by the "Questionnaire Review Committee" (Messrs. Lundquist, Johnston, Jones, Tammen), lists the Committee to whom cognizance was "assigned" and finally shows which of the Council's program (if any) is working on the problem.

(For information at this point, Fig. 11a and 11b at the end of the report list the various research programs and special projects that have been set up by the Council.)

3.3. SUGGESTED PROJECTS

The listing in the last column of Fig. 8 gets a bit ahead of the game. The outgrowth of the planning thus far was to indicate specific needs for projects. Assignments would have to be made to committees or small groups--and this leads us to the next topic.

-
- (2) Lundquist, Johnston, Jones, and Tammen; "SUMMARY OF ANSWERS TO QUESTIONNAIRE", CRC Report No.0.1, March 25, 1946.
 - (3) CRC, "PROSPECTUS", Revised May 11, 1953.

4. T H E C O M M I T T E E S A N D
T H E I R A S S I G N M E N T S

4.1. SETTING UP THE COMMITTEES

The main committees are shown in Fig. 4. The Technical Board was set up at the first Annual Meeting (9/45) with the responsibility to organize the committees and to carry out the survey of important problems.

The Steering Committee of the Committee on Research was set up in May, 1947 by the Technical Board to correlate the literature survey and to coordinate subcommittee activity.

The first four Research Subcommittees (A to D) were set up in September, 1945 to handle specific assignments that would subsequently be received from the Technical Board.

The remaining Subcommittees (E to G) were appointed in 1948 to supervise particular areas of research.

The Recommended Practice committee was also set up at the time of the first Annual Meeting, to serve the important function of translating the results of research work into practical use.

4.2. PROBLEMS ASSIGNED TO COMMITTEES

In March of 1946 questionnaires (Q-1) were distributed. At a Council meeting in October, 1946, it was indicated that a specific program of study was required to give direct evidence to possible financial sponsors of a need for the C.R.C.

From these two sources, then, came a request to Committee D (October, 1946) to prepare a program of research. This was submitted in November, 1946, by the committee which consisted of Messrs. Newmark (Chairman), Bleich, Hussey, Julian, Wessman, and Winter. Comments were in from the main Committee on Research by December 1946. These dates are mentioned to show the speed with which this operation was handled.

The resulting summary of needed research is shown in Fig. 9 under the heading "Initial Research List". The cognizant committee is shown and indication is given as to whether or not a project was established.

Growing out of similar needs as led to the first list, two later lists were prepared, known as "Research List No. 1" and "No. 2" as shown in Fig. 9.

Several additional projects grew out of existing studies or specific requests to the Council.

A summary of the broad assignments to the various committees is shown in Fig. 10. This list does not contain all the projects because it is designed to show the broad scope of assignments. As mentioned earlier, Fig. 11 lists the Council's projects.

5. S U M M A R Y

1. The Council was formed:
 - (1) because information was needed to write a column formula for high-strength steels.
 - (2) due to an evident non-uniformity in specifications and building codes, many of whose provisions evidently covered the same applications.
 - (3) in order to expand the representation of what previously had been an A.S.C.E. committee.
2. The C.R.C. was suggested by practicing engineers as an out-growth of specific needs from industry. The organizing effort was supplemented in part by professors in universities.
3. The program was set up by
 - (1) first asking practicing engineers (and others) what problems they thought were important.
 - (2) surveying the literature.
4. The Research Committees were set up to handle assignments that grew out of the program planning, to supervise specific projects, and to summarize the existing state of knowledge (as requested).
5. Certain "recommended practice" activities were formulated in the hope that eventually the information "that is now known" could be translated into practical design procedures, thereby bringing about the needed standardization, economy, and public safety.

CHRONOLOGY OF CRC

-9

THE NEED

Oct. 1939 Column Formulas -- H.S. Steels
May 1940 Revisions, N.Y. Building Code
Jan. 1941 Evaluation - Plate Buckling Report
Sept. 1941 Expand Committee Representation

ORGANIZATION

----- Prior ASCE Committee (D.S.M.)
Dec. 1941 National Agency is Needed
Aug. 1943 Formation of CRC Suggestion
Jan. 1944 Approval by ASCE
June 1944 Funds Voted By Engineering Foundation
Feb. 1945 Meeting of Organizing Committee
Sept. 1945 First Annual Meeting

THE PROGRAM

Mar. 1946 Survey of Current Problems
May 1947 Critical Literature Review
May 1947 Problems From Research Committees
Sept. 1947 Current Research Questionnaire

ASSIGNMENTS

Sept. 1945 Tech. Board-Research-Recommended Practic
1946--1947 Committees A-D (1945)
1949--1950 Committees E,F,G (1948)

FIGURE 1

PURPOSE OF CRC

FORUM

National Scope
Problems Presented for Investigation
Evaluation of Proposed Studies
A Basis for Program

LITERATURE

Critical Survey - Worldwide
Provide Reference Material
Existing Gaps

RESEARCH

Specify the Program
Organize and Administer Projects
Stimulate and Guide Projects

APPLICATION

Summarize Results of Projects
Study Application of Results to Design

DESIGN PROCEDURES

Develop Consistent Rules

ADOPTION OF RULES

Designers - Specification Groups

PUBLICATION

Results of Research
Council Recommendations

FIGURE 2

COLUMN RESEARCH COUNCIL OF ENGINEERING FOUNDATION
REVISED BY-LAWS *

PURPOSES

The general purposes of the Column Research Council shall be:

- a. To organize, maintain, and administer a national forum where problems relating to the design and behavior of columns and other compression elements in metal structures can be presented and pertinent structural research problems can be proposed for investigation, with the assurance of an evaluation of all problems proposed and of support for those projects adjudged important.
- b. To digest critically the world's literature on structural behavior involving compression elements and the properties of metallic materials available for their construction, and make the results widely available to the engineering profession.
- c. To organize and administer cooperative research projects in the field of compression elements.
- d. To stimulate, aid, and guide column research projects on the foregoing problems in the engineering colleges, endowed laboratories, and other research laboratories.
- e. To study the application of the results of this program to the design of compression elements.
- f. To develop a comprehensive and consistent set of formulas or rules covering their design.
- g. To promote the widest possible adoption of such formulas by designers and specification-writing bodies.
- h. To publish and disseminate original research information within the field of the Council.

*Excerpts from Revised By-Laws as amended August 15, 1951.

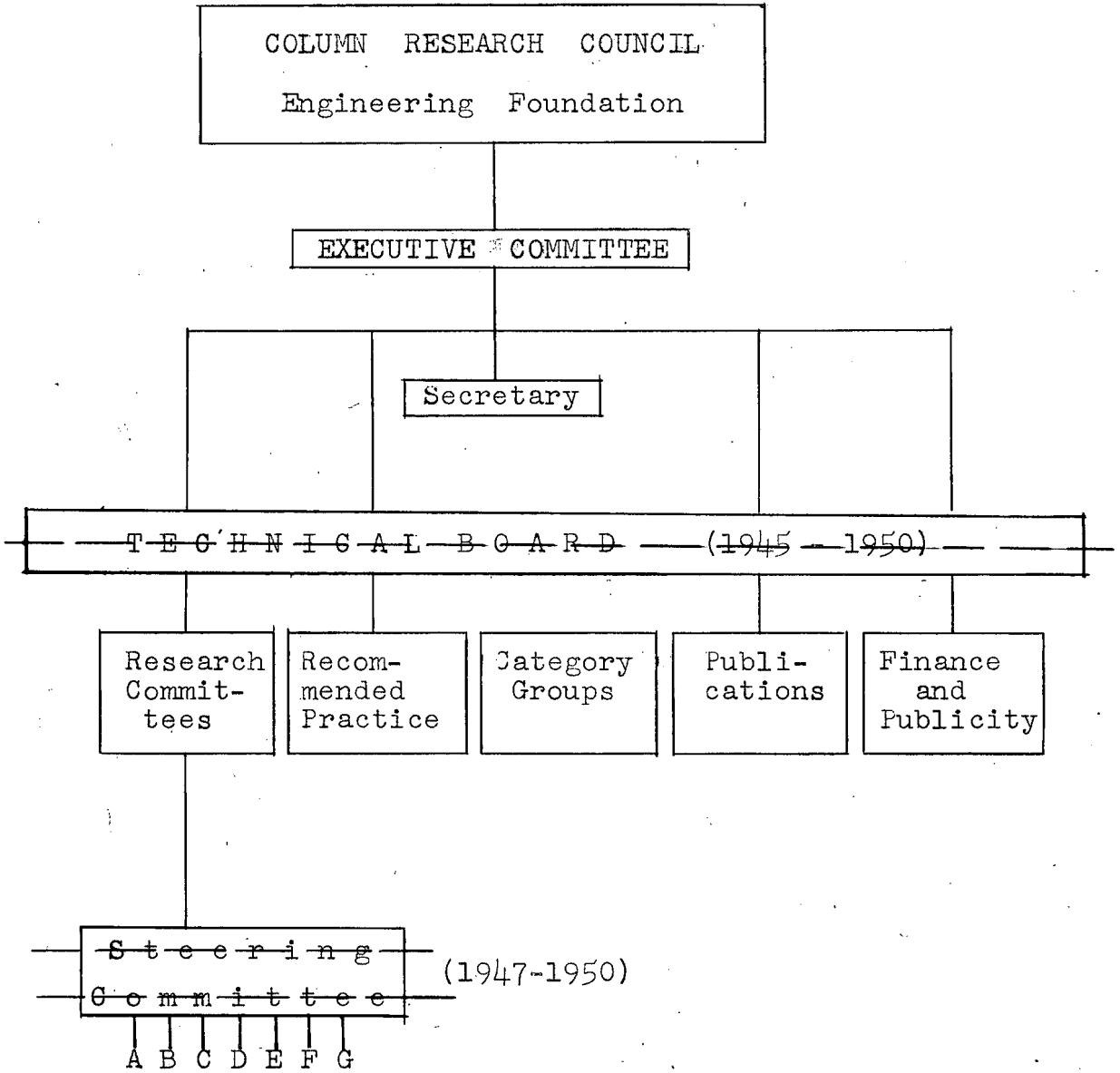


FIGURE 4

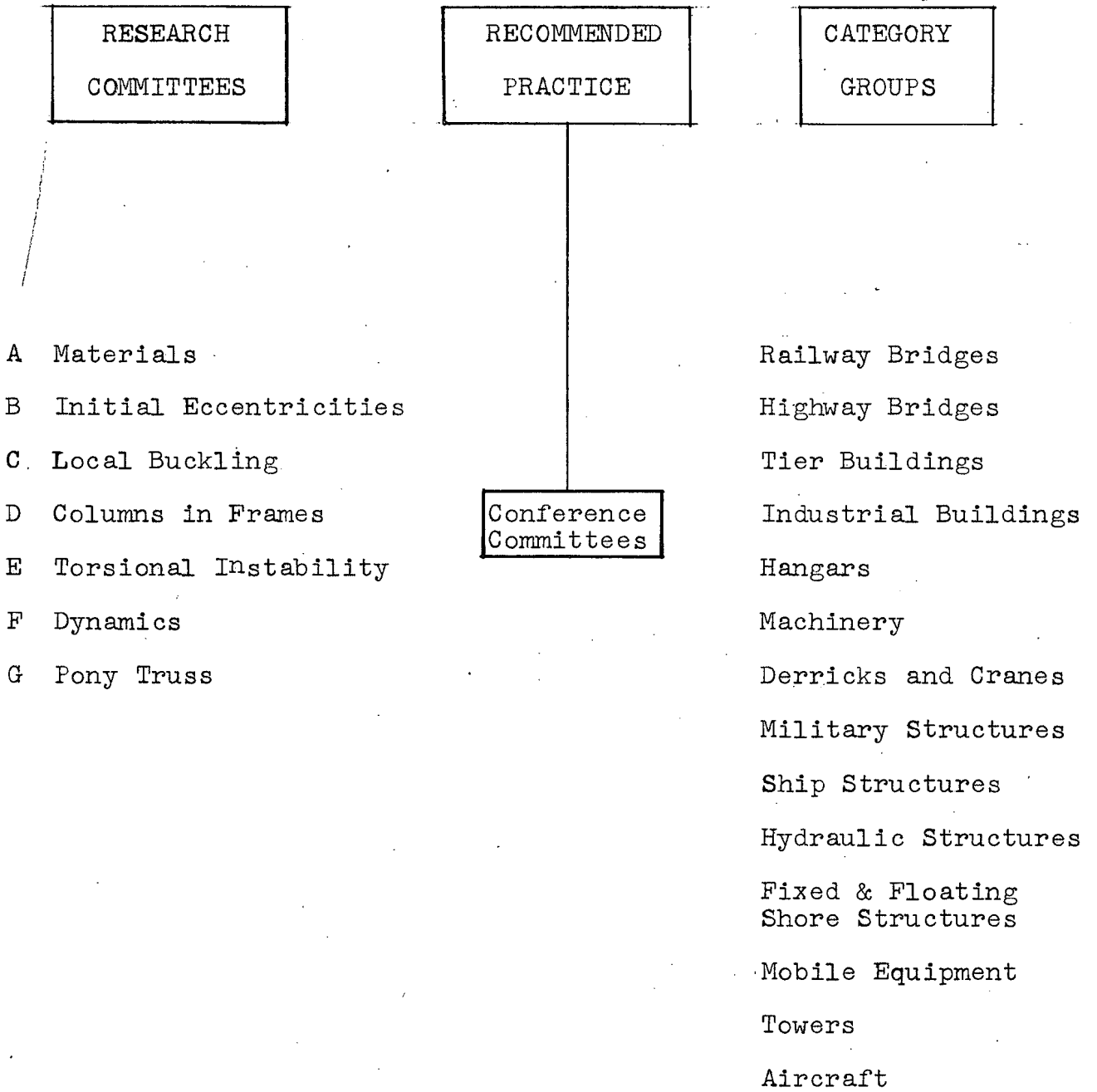


FIGURE 5

DEVELOPMENT OF PROGRAM

1. SURVEY OF CURRENT PROBLEMS (1946)
 - (a) What are the important problems
 - (b) Suggestions for Research
 - (c) Anticipated Use of Metals

2. LITERATURE SURVEY AND EVALUATION (1947)
 - (a) Does Existing Information Provide the Answers
 - (b) List of Important References
 - (c) Recommended Research
 - (d) Provide an Up-To-Date Treatise

3. CURRENT RESEARCH SURVEY (1947)
 - (a) What Work is in Progress or is Planned
 - (b) What New Information is Available

4. PROJECT RECOMMENDATIONS FROM COMMITTEES (1946)

FIGURE 6

QUESTIONNAIRE

1. What are the most important structural problems, involving stability against buckling, that you or your organization has encountered? In your answer to this question, please cover the following points, in addition to any other that you may consider:
 - A. A clear description of the member of part of the member involved.
 - B. The specification and specific design formula used, if any.
 - C. A specific reference to any research which substantiates the specification or formulas.
 - D. Your opinion or experience to the adequacy or inadequacy of the specification and formulas.
2. What structural design problems, involving stability against buckling, have you encountered or do you expect to encounter in the future, on which additional experimental or analytical research is needed? In your answer to this question, please indicate the factors which you believe have an important bearing on the buckling strength, and where the emphasis in research should be placed and why.
3. What metals do you expect to use in future structural designs? In your answer to this question, please specify clearly the particular alloys.

FIGURE 7

(Questionnaire No. 1 of Column Research Council)

	Review Committee	Com. Assign.	Project Set up
<u>I. COLUMNS THAT FAIL BY BENDING DEFLECTION</u>			
1. Axial force with end moment (frame and truss members)	Do Most Work Here	D	Lehigh (0.2.D) Cornell (0.3.D) Penn State (0.4.D) Furdue (0.5.B)
2. Effect of initial eccentricities or initial deflections		D B	
3. Effective length of truss members		D	Cornell (0.3.D) Penn State (0.4.D)
4. Columns with perforated cover plates		C	-- (1.2.C)
5. Effect of residual stresses		A	Lehigh (3.5.A)
<u>II. FAILURE DUE TO COMBINED BENDING AND TWIST</u>			
1. Angle and Tee struts	Do Some Work	-	-- Alcoa (0.7.E) Illinois (0.9.E) Columbia (0.10.E)
2. Axial force with bending and torsion		E	Brown (1.5.E)
3. Buckling of compression flange of beam		E	Washington (1.4.E)
<u>III. LOCAL BUCKLING OF THE CROSS-SECTION</u>			
1. Local instability failures of columns	Do Little Work (NACA)	C	Stanford (0.6.C) Lehigh (0.8.C) -- (1.1.C)
2. Flat or curved plates, with or without stiffeners		-	--
<u>IV. DESIGN AND EVALUATION OF BRACING MEMBERS</u>			
1. Design of column bracing and evaluation of bracing effect on strength	Do Some Work	-	--
<u>V. PLATE GIRDER PROBLEMS</u>			
1. Design of intermediate stiffeners	No Work (Current Research)	-	--
<u>VI. DESIGN OF THROUGH BRIDGES (TOP BRACING OMITTED)</u>			
	Yes	G	Penn State (2.5.G)
<u>VII. MISCELLANEOUS PROBLEMS</u>			
1. Material properties of metals and alloys	If find sponsor	A	Lehigh (3.1.A, 3.3.A) -- (2.1.A)
2. Time effects		F	--
<u>VIII. SUGGESTIONS</u>			
1. Bibliography	Existing	SC	Eleich (0.1.C)
2. Standardize Column Formulas	Objectives	RP	--

FIGURE 8a

SPECIFICATIONS MENTIONED
IN REPLIES TO QUESTIONNAIRE

		<u>Times Mentioned</u>
1.	A.R.E.A.	17
2.	A.A.S.H.O.	11
3.	A.I.S.C.	5
4.	A.S.C.E.	3
5.	A.W.W.A.	2
6.	ANC-5	1
7.	N.Y.C. Building Code	1
8.	National Board of Fire Underwriters	1
9.	Factory Mutual Fire Insurance Co.	1

METALS CONTEMPLATED FOR FUTURE USE

1.	Structural silicon steel (ASTM - A94)	16
2.	Aluminum alloys	12
3.	Low alloy structural steel (ASTM-A242)	8
4.	Structural nickel steel	6
5.	High strength alloy steel (SAE 4130 or 4340)	3
6.	Stainless steel	3
7.	Magnesium alloys	2

FIGURE 8b

	Committee	Project
<u>INITIAL RESEARCH LIST (Committee D)</u>		
1. Bibliography	SC	Yes
2. Compression Members in Trusses	D	Yes
(1) Action of members (restraint)	D	Yes
(2) Effect of secondary deformation and imperfections (with B)	B	Yes
(3) Field observations (with AAR)	-	-
3. Compression Members in Frames	D	Yes
4. Methods of Design of Compression Members in Frames	D	Yes
5. Column and Connection (Local) Details (with C,E)	C	-
6. Biaxial Flexure and Torsional Buckling	E	Yes
7. Pony Truss	G	Yes
8. Bracing Requirements	-	-
9. Effect of Residual Stresses	A	Yes
<u>RESEARCH LIST NO. 1</u>		
1. Local instability of built-up structures	C	-
2. Correlation of existing information on perforated cover plates	C	Current Research
3. Development of Numerical and Approximate Methods of Analysis for Compression Members Having Varying Section or Varying Properties	D	-
4. Lateral Buckling of Beams	E	Yes
5. Interaction Formula for Combined Bending Moment and Axial Load	E	Yes
<u>RESEARCH LIST NO. 2</u>		
1. Determination of Basic Stress-Strain Curves in Structural Metals	A	in part
2. Critical literature survey on behavior under impact and vibration	F	-
3. Response to dynamic loading	F	-
4. Response to fluctuating stress components	F	-

FIGURE 9

A S S I G N M E N T S

TECHNICAL BOARD

Organize and Give Direction to Committees
Determine Important Problems

RESEARCH

SC

Correlate Literature Survey Activity
Coordinate Subcommittees

ALL

Submit Programs Based on Survey
Review and Recommend Needed Research
Guide Research Programs
Process Reports to Practical Applications

A

Tangent - Modulus Formula
Notes on Compression Testing

C

NACA Research on Plate Buckling

E

Recommendation for Design Specifications (A.R.E.A.)

PUBLICATIONS

Publication of Recommendations
Dissemination of Information
Translations

RECOMMENDED PRACTICE

Chart of Column Problems
Application of Results to Practice
Comprehensive Specification

LIST OF COLUMN RESEARCH COUNCIL PROJECTS

(current projects are underlined)

<u>Number</u>	<u>Institution</u>	<u>Project Director</u>	<u>Investigation</u>
*0.1.SC	Frankland & Lienhard	Bleich	Literature Survey & Evaluation
°0.2.D	<u>Lehigh</u>	Beedle	Columns in Continuous Frames
<u>0.3.D</u>	<u>Cornell</u>	Winter	Buckling of Rigid-Joint Structures
*0.4.D	Penn State	Kavanagh	Analysis and Design of Columns in Trusses and Frames
<u>0.5.B</u>	<u>Purdue</u>	Hayes	Effect of Initial Eccentricities on Column Capacity
*0.6.C	Stanford	Benjamin	Built-Up Columns
*0.7.E	Alcoa	Templin	Lateral Buckling of Channels, I-Beams and Z-Beams
°0.8.C	<u>Lehigh</u>	Thürlimann	Inelastic Instability
*0.9.E	Illinois	Austin	Torsion Buckling of Columns
*0.10E	Columbia	Salvadori	Lateral Buckling
+1.1.C	----	----	Local Instability of Built-Up Structures
°1.2.C	<u>Lehigh</u>	Thürlimann	Perforated Cover Plates
***1.3.D	Illinois	Newmark	Numerical Methods of Analysis
*1.4.E	Washington	Hechtman	Lateral Buckling of Beams
*1.5.E	Brown	Drucker	Interaction of Compression and Bending Forces
+2.1.A	----	----	Determination of Basic Stress-Strain Curves in Structural Metals
+2.2.F	----	----	A Literature Survey & Critical Evaluation of Theoretical Studies & Experimental Work on the Behavior of Metallic Compression Members Subject to Impact and Vibration

*This research project has been completed.

°Supported without funds at present.

+Program of research approved but project not yet established.

**Awaiting financial support.

***Withdrawn by the institution for the time being.

+2.3.F	----	----	Response of Compression Members to Dynamic Loading
+2.4.F	----	----	Response of Compression Members Subjected to a Fluctuating Axial Component of Stress
<u>2.5.G</u>	<u>Penn State</u>	Holt	Stability of Bridge Chords Without Lateral Bracing
*3.1.A	Lehigh	Beedle	Influence of Residual Stress on Column Strength (Pilot Program)
+3.2.F	----	----	Failure of Columns Due to Blast Load
<u>3.3.A</u>	<u>Lehigh</u>	Beedle	Residual Stress and the Com- pressive Properties of Steel

Special Projects of the Column Research Council

- *1. Questionnaire Survey (No.1) on current problems in the design of compression members.
- *2. Questionnaire Survey (No.2) of current research in the field of structural instability.
- *3. Statement on the desirability of the tangent modulus formula.
- *4. Notes on compression testing and the column strength curve.
5. Chart of column problems.
6. Translation of German specifications on the design of compression members.
- *7. Translation of report by Mirko Ros, "Buckling of Columns".

+Program of research approved but project not yet established.

*This project has been completed.

**Awaiting financial support.

II. REPORTS FROM VARIOUS RESEARCH COMMITTEE CHAIRMEN
ON WORK OF THE COUNCIL

Research Committee A - Mechanical Properties of Materials
by Bruce G. Johnston, Ch.

For a number of years under the chairmanship of Dr. William Osgood and currently under its present chairman, this committee has been concerned primarily with the relation between material (metal) properties and column strength. The early questions, as we have been reminded by Lynn Beedle, were as follows:

1. What metals to consider;
2. The effect of Residual Stress and variation in metal properties;
3. Did the tangent modulus theory provide a suitable basis for relating properties to column strength in all cases - or was structural steel with its nearly elastic behavior up to a flat yield level an exception?
4. Was there already available enough stress-strain information or was more information needed.

Through the years much progress has been made. As a result of the Research Projects at Lehigh on "Residual Stress and the Compressive Properties of Steel" implemented by work of the committee, the following summary is made:

1. The tangent modulus theory does adequately provide a basis for the prediction of column strength but, especially in the case of structural steel, more than the stress-strain properties of the individual coupon tests must be taken into account in order to obtain the proper strength prediction. Other considerations which must be included are:
 - a. The shape of the cross-section;
 - b. The variation in stress-strain properties across the section;
 - c. The state of residual stress induced by the cooling of hot-rolled shapes,
 - d. The rate of strain at which the column and/or the material test (coupon) is tested.

Reference should be made to TECHNICAL MEMORANDUM No.1, "The Basic Column Formula", and to the forthcoming memorandum on "Basic Column Strength".

2. Through surveys, one of which was carried out by Jonathan Jones, it has been established that there was, and still is, insufficient data on the stress-strain characteristics of structural metal to come up quickly with column strength formulas covering a wide variety of metals. Those data that could be collected have been turned over to Lehigh for use in their Research.
3. Proper procedures have been set up for desirable test techniques for the determination of basic material stress-strain properties. See TECHNICAL MEMORANDUM No.2, "Notes on Compression Testing".
4. Through the previously mentioned program at Lehigh, proper procedures and quantitative data are being obtained on these subjects to provide the accurate evaluation of the column strength curves for those metals to be considered. Progress Reports have been distributed regularly by the Lehigh group.
5. A third Technical Memorandum is now under review on "Basic Column Strength". It is the intention of this memorandum to explicitly show how to convert the information on stress-strain curves and residual stress properties into equations for the determination of average stress at column failure loads. Such an equation can then form the basis for setting up column design formulas.

In conclusion - - It would seem that the questions posed this committee in its initial assignment have either been answered or are still actively being pursued. Weakness in our present program may possibly lie in over emphasis on structural grade steel because of its widespread interest and use. We have given but little attention to high strength steels and light metals.

Research Committee C - Local Instability
by G. Winter, Ch.

1. Up to 1950 a large amount of work on local buckling had been carried out but had not been collected and was largely unknown outside of aeronautical engineering. Committee C in two activities has promoted systemization and presentation of such information;

- (a) through its detailed review of the pertinent chapters of Bleich's book with, many suggestions of inclusion of material, and
- (b) through the promotion and detailed advance review of the paper "Buckling Stresses for Flat Plates and Sections" by Stowell, Heimerl, Libove and Lundquist.

This combination presented the entire available evidence on (i) buckling of flat plates under a variety of stresses and conditions of edge support; (ii) buckling of plate assemblies such as channels, I's, Z's, Box-sections, etc., (iii) buckling of above not only in the elastic but also in the plastic range. In addition, somewhat limited information is included in both sources on the important topic of post-buckling strength.

2. The above gives the basis for the determination of safe b/t-ratios, (safe against buckling up to a specified stress, say, the yield point).

Around 1949-50 some of us began to realize that if ultimate or limit design were to be used for steel structures, plates like flanges would have to be safer, i.e., they would have to sustain larger rotations without buckling. A project was instituted at Lehigh to which Committee C is an advisor. The writer prepared a tentative note on this subject which was distributed to Council. Committee C analyzed the program and results of the Lehigh study in great detail and, it is believed, significantly influenced the direction of the investigation.

This work is not complete, but Lehigh has been able to make the following tentative recommendations:

WF compression flanges	b/t = 17
Webs in Bending	not ready
Webs in Compression	d/w = 34 for strain hardening
	d/w = 45 for initial yield

This would eliminate a number of presently rolled sections, and also would require tightening up of existing b/t-rules when permitting ultimate design.

3. Committee C has reviewed existing knowledge on buckling strength of built-up or fabricated sections and has found it lacking. It has, primarily through the efforts of E.C. Hartmann, produced a bibliography and formulated a program of research in this important field. There is evidence, in the somewhat one sided work by Norris and Associates at MIT, that any intermittent connecting, no matter how closely spaced, weakens buckling strength. The importance of this is obvious.

4. The Committee has reviewed existing knowledge on members with perforated cover plates, has drawn Messrs. Erickson, Higgins, and Ruble extensively into the discussion, and has formulated a detailed outline of an evaluative report of existing knowledge, to satisfy requirements of practical design. This was prepared primarily by Dr. Bleich. One of the chief values of the very extensive correspondence was probably the focussing of the question.

A report, produced by Lehigh for Masters without Committee C participation and ostensibly without reference to the Committee outline, follows this outline almost exactly and answers exactly the questions asked in the outline. Incidentally, Dr. Bleich, during the committee's work, anticipated most of Lehigh's answers almost exactly. The chief value of the intelligent Lehigh report is to present in readable and logical fashion those general conclusions which informed readers of existing material, such as Bleich, had arrived at by themselves.

5. Topics that have only been touched upon but may need more attention are:

- (a) interaction of local and column buckling, on which a note by the speaker was distributed to council in 1953 outlining the basis on which this question is handled in the AISI specifications;
- (b) post-buckling strength, particularly of wide, thin plates;
- (c) buckling strength of cylindrical tubes.

While all these topics are of only limited interest for conventional steel construction, they are of sizeable importance in other fields, such as light-gage steel, and non-ferrous metal construction, shell, tank, and vessel construction, etc. It has been, at least, the writer's understanding that CRC is not limited to conventional steel construction for bridges and buildings, although at times this seemed to be so.

6. From the viewpoint of basic knowledge likely to be of considerable practical consequence in the future, the most interesting development in work with which the Committee is connected seems to be this:

From work at Lehigh primarily, but anticipated by prior work elsewhere, it is becoming clear that the yield

process in steel, being discontinuous, non-homogeneous and anisotropic, distinguished this material from all other engineering metals. In particular, the usual theories of plastic buckling, somewhat shaky in themselves, do not seem to apply at all well to steel. On the other hand in well designed structures most buckling is in the plastic range since buckling in the elastic range in most cases means uneconomical use of material in view of under-stressing. It would seem that future work on local buckling of steel structures will be sizeably influenced by this closer, but as yet quite incomplete, understanding of the yield process of steel.

Local plastic buckling, even in homogeneous, isotropic material is an anisotropic process, which accounts for the difficulty of its analysis. The peculiar nature of steel compounds this difficulty and therefore, for some time to come, it will make reliable analysis unlikely, basic information will have to come primarily from experimental evidence.

Research Committee D - Columns in Trusses and Frames
by N. J. Hoff, Ch.

Research Committee D began its activities by discussing in detail the unsolved problems relating to the behavior of compression members in trusses and frames. On the basis of these discussions it recommended that three research projects be initiated; these projects were given the numbers 0.2.D, 0.3.D, and 0.4.D.

An investigation of the problems described in Project No. 0.2.D was begun under Professor Bruce G. Johnston at Lehigh University with financial help from an outside sponsoring agency without monetary contributions from the Column Research Council. Work along similar lines is still continuing at Lehigh under the direction of Professor Lynn S. Beedle. The work has been discussed at length in meetings of Committee D and technical reports issued under the project have been made available continuously to the Committee in spite of the lack of C.R.C. financial support. For this continued cooperation Committee D wishes to express its appreciation to Lehigh University.

Work under Project No. 0.3.D was initiated at Cornell University under the direction of Professor George Winter in February 1949. This investigation has been carried on continuously throughout the intervening years and is scheduled for completion this summer. It has been supported by considerable appropriations from the Column Research Council.

A number of excellent investigators have contributed to the success of this project; among them Professor P.P. Bijlaard should be mentioned here.

The third project, No. O.4.D, began at Pennsylvania State College under Professor T.C. Kavanagh in April 1950. The Column Research Council has contributed only a small sum toward its expenses but Committee D has received the benefit of the technical reports issued under the project.

A large number of technical reports have been issued under the three research projects. They have been distributed to the members of the C.R.C.

In the opinion of Research Committee D, a reasonably complete understanding of the behavior of compression members in trusses and frames is available today in the fully elastic range. This understanding is based on extensive research work carried out under the cognizance of C.R.C. as well as elsewhere. In addition, the effect of plastic deformations has been explored in a number of cases of practical importance and an investigation dealing with the loss of strength caused by initial stresses has made considerable progress.

Yesterday morning Research Committee D decided to prepare a report for transmittal to the Committee on Practical Applications. In the opinion of the membership of the committee, a number of valuable improvements can now be made in the codes. Some of them were pointed out in the report presented by Professor G. Winter at the Annual Meeting of the C.R.C. in 1954. Professor Winter undertook the job of consolidating his report with the suggestions made by the discussors and of condensing further the presentation. Dean L.E. Grinter promised to send suggestions and criticisms to the members of Committee D. On the basis of this material the Committee will discuss the report by letter as well as orally and will send its final recommendations to the Executive Committee at the earliest possible date.

This report would be incomplete without mentioning the devoted work done by the retiring chairman, Professor N. M. Newmark.

Research Committee E - Lateral Buckling
by H.N. Hill, Ch.

Committee E has supervised or served in an advisory capacity on five projects all relating to the problems of the lateral-torsional buckling of beams and the failure of members under combined compression and bending.

In addition to the supervision of these projects, Committee E has also worked with other bodies of Column Research Council in the preparation of recommendations for design specifications dealing with these two problems. I will speak briefly of each of the projects taking them in the order in which they were started.

0.7.E - Lateral Buckling of Channels, I-Beams and Z-Beams

This is a project which was underway at the Aluminum Research Laboratories of Alcoa at the time sponsorship was adopted by Committee E. As originally conceived, this sponsorship covered two items:

1. Lateral Buckling of Channels and Z-Beams Under Pure Bending
2. Lateral Buckling of Eccentrically Loaded I-Section Columns

The latter item was expanded beyond the original concept.

The results of the first item of this project were reported in a paper appearing as ASCE Proceedings Separate No. 334, "Lateral Buckling of Channels and Z-Beams" by H.N. Hill, November 1953. Although the problem of the bending of channels and Z-beams is generally one of unsymmetrical bending, this work demonstrated the importance of the section property called the torsion-bending constant in calculating the lateral buckling strength of members of unsymmetrical cross section. It was shown, however, that the use of the Timoshenko formula for symmetrical I-sections could be applied to channel members of usual proportions with sufficient accuracy for design purposes. Use of the I_d/bt simplification of the Timoshenko formula, however, greatly underestimates the strength of such members.

The second part of this project dealing with members under compression and bending resulted in a paper presented at the First National Congress of Applied Mechanics in 1951, "Lateral Buckling of Eccentrically Loaded I- and H-Section Columns" by H.N. Hill and J.W. Clark. Results of extensions of this original project have been published by ASCE as follows:

1. Proceedings Separate No. 34, "Lateral Buckling of Eccentrically Loaded I-Section Columns" by H.N. Hill and J.W. Clark, Sept. 1950.
2. Proceedings Separate No. 299, "Plastic Buckling of Eccentrically Loaded Aluminum Columns" by J.W. Clark, Oct. 1953.
3. Proceedings Separate No. 300, "Designing Aluminum Alloy Members for Combined End Load and Bending" by H.N. Hill, E.C. Hartmann, & J.W. Clark, Oct. 1953.

This last publication is more or less of a summary report describing methods for designing aluminum alloy beams, columns, and beam-columns.

Although this Alcoa project was related specifically to aluminum alloys, the results obtained are in many respects directly applicable to steel design.

0.9.E - Torsional Buckling of Columns

This is a project in which Committee E served in an advisory capacity. The project was really a combination of projects sponsored by the Bureau of Public Roads and by the Office of Naval Research at the University of Illinois. The projects were under the direction of Professor Austin and had to do with some model tests on large columns and numerical methods for calculating the lateral-torsional buckling strength of beam-columns.

Two reports on this project were supplied to Committee E as well as to Committees A and C. The reports were considered by Committee E to be of considerable merit and were referred to the Committee on Publication.

As an outgrowth of the above-mentioned Office of Naval Research Project, a paper was presented to ASCE in October, 1954 and published as Proceedings Separate No. 673, "Lateral Buckling of Elastically End Restrained I-Beams" by W.J. Austin, T.P. Tung, and S. Yegin, April, 1955. This paper provided solution for many practical cases of end restrained beams.

0.10.E - Theoretical Solutions to Lateral Buckling Problems

This project was conducted under the direction of Professor Salvadori at Columbia University and involved numerical calculations for lateral-torsional buckling of beam-columns under many practical conditions of loading and restraint. The work was reported in two publications by ASCE:

1. Proceedings Separate No. 291, "Lateral Buckling of I-Beams Under Thrust and Unequal End Moment" by M.G. Salvadori, Oct. 1953.
2. Proceedings Separate No. 607, "Lateral Buckling of Eccentrically Loaded I-Columns by M.G. Salvadori, Jan. 1955.

This work was valuable in that it provided for the first time solutions for many conditions of practical interest.

1.4.E - Lateral Buckling of Steel Beams

This project was conducted at the University of Washington under the direction of Professor R.A. Hechtman. The project was undertaken because, to quote from the proposal for the project, "there are insufficient experimental test results to establish the adequacy of this (the L_d/bt) formula". The program included tests on rolled beams of various depths with different types of end restraint.

During the conduction of this project, three progress reports were submitted as follows:

May, 1951
May, 1952
April, 1953

The final report was submitted to Committee E for review in June, 1954. The results were presented in a paper to ASCE by Professor Hechtman in October, 1954. The final report has been approved for publication by ASCE as a Proceedings Separate and it is expected that it will be available in this form within several months.

The results of this project indicated the reliability of the L_d/bt formula for simply supported beams of large L_d/bt and verified the desirability of a transition curve between the L_d/bt curve and the basic allowable cut off. The tests also indicated the strengthening effect of end connections.

1.5.E - Interaction Formulas for Combined Bending Moment and Axial Stress

This project which was conducted under the direction of Professor D.C. Drucker at Brown University was instituted to study the validity of the interaction formula (sometimes referred to as the AISC formula).

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1$$

The project was later extended to include a study of the AASHO and AREA Specifications for columns under combined thrust and bending moment. Three progress reports were prepared as follows:

1. "Investigation of the Interaction Formula $f_a/F_a + f_b/F_b \leq 1$ " by J. Zickel and D.C. Drucker, April 1951.
2. "Investigation of AASHO and AREA Specifications for Columns Under Combined Thrust and Bending Moment" by B. Thürlimann and D.C. Drucker, May 1952.

3. "Deformations of and Stresses in Initially Twisted and Eccentrically Loaded Columns of Thin Wall Cross Section" by Bruno Thürlimann, June 1953.

These reports cover an analytical study of the problem as well as a review of numerous test results available in the literature. The results of this project were essential in arriving at a recommended design specification for beam-columns.

Recommended Design Specifications for AREA

In June of 1953 Committee E advised that several of the projects of Committee E were approaching a state in which they should be referred to the Committee on Practical Applications. In October of 1953 the Column Research Council received a request from Committee 15 of AREA for "a definite recommendation on the practical application of the interaction formula and the lateral buckling formula with supporting data". Mr. Hardesty accordingly called upon Committee E for a summary report aimed at supplying the necessary supporting data for the AREA request. Committee E met in October, 1953 and set up a subcommittee composed of John Clark, Bruno Thürlimann, and Robert Ketter to prepare such a summary report. This was a sizeable undertaking since it involved not only the results of projects which have been under Committee E sponsorship, but also such related material as was available. The subcommittee performed an outstanding job and their report was submitted to Committee E for approval in April, 1954. Committee E then submitted their report to Mr. Hardesty, the Executive Committee, the Committee on Practical Applications, and the Committee on Recommended Practices in May, 1954. This report consisted of the subcommittee summary report with minor changes and specific recommendations from Committee E. These recommendations were of a general nature and indicated principles that might be followed in recommending improvements in design specifications for beams and beam-columns.

Committee E continued to work with the Committee on Practical Applications and the Executive Committee in the preparation of a recommendation which was finally submitted to AREA in October, 1954. In arriving at the finally recommended specification changes, the recommendations of Committee E were modified and amplified in an attempt to give a more complete coverage of the subject. Although it is recognized that the recommended specifications lack something in completeness, it is thought that they represent a distinct improvement over that which they are intended to replace.

At the present time, Committee E has before it only one assignment. This has to do with a consideration of whether or not an investigational study of the lateral buckling of built-up girders should be proposed.

Research Committee F - Dynamics
by N.J. Hoff, Ch.

The problems under the cognizance of Research Committee F pertain to the dynamic loading of columns. Four of them were described under Project Nos. 2.2.F, 2.3.F, 2.4.F, and 3.2.F, and are titled as follows:

- 2.2.F A Literature Survey & Critical Evaluation of Theoretical Studies & Experimental Work on the Behavior of Metallic Compression Members Subject to Impact and Vibration
- 2.3.F Response of Compression Members to Dynamic Loading
- 2.4.F Response of Compression Members Subjected to a Fluctuating Axial Component of Stress
- 3.2.F Failure of Columns Due to Blast Load

The specifications of Project Nos. 2.3.F and 2.4.F were slightly modified at the recommendation of the Committee made on April 22, 1952.

In 1952 the committee was informed that a project sponsored by the Sandia Corporation at Lehigh University under the direction of Professor Lynn S. Beedle, namely a literature survey, was very much like Project No. 2.2.F. The committee gladly accepted co-sponsorship of the work when so requested by Professor Beedle.

When during the same year a request was received from the Sandia Corporation to recommend a detailed research project, ask for bids, select an organization to carry on the project and supervise the work, the Committee held several meetings to comply with the request. A specification was sent to a number of selected research groups connected with various universities and six proposals for research were received. Of these one was recommended for the awarding of a contract, and a second was selected as an alternate. Unfortunately Sandia Corporation informed C.R.C. that at the time of the receipt of the recommendations it was no longer in a position to subcontract research work. It forwarded the proposals, as well as the endorsement of the C.R.C., to the Armed Services Special Weapons Panel. This agency in turn decided against the support of the project.

Since 1952 Research Committee F has held few meetings and has transacted little business. It has been cognizant of the fact that work of a classified nature has been going on in various institutions under the sponsorship of military organizations. The Committee hopes that enough non-classified information will become available in the not-too-distant future on the dynamic aspects of column behavior to make a review of the concepts underlying the specifications on dynamic effects in compression members not only possible but also most desirable.

Committee on Recommended Practice

by J. Jones, Ch.

After Committee E delivered its report on May 13, 1954, the Committee on Practical Applications took it up and offered on June 4 a draft of a proposed recommendation to A.R.E.A. In order that this recommendation might be complete enough to offer a replacement for everything in the existing A.R.E.A. Specifications for Railway Bridges, this draft went in some instances beyond any specific recommendation in the Committee E report. This seemed to be the only way to bring up forcefully this question of complete coverage.

Committee E took the expected exception to this extension of its recommendations. After further correspondence and meetings, a final draft was agreed to and submitted by Mr. Hardesty to A.R.E.A. on October 25, 1954. As nearly as I can see this recommendation covers the field indicated in the June 4 draft with the following exceptions:

1. Members symmetrical about a longitudinal vertical plane but unsymmetrical about horizontal plane (tees, unsymmetrical I's).
2. Channels, zees and other members not symmetrical about longitudinal vertical plane.
3. A replacement for "bt" for girders not symmetrical about both axes.
4. Protection against buckling of bottom flanges of girders, where subjected to compression near points of contraflexure.

It was agreed by the Committee on Recommended Practice, that these questions have little or no importance in specifications for railway bridges. They arise continually in buildings, and from time to time in highway bridges. The Committee on Recommended Practice would prefer to include recommendations on these four topics, in any amendments it may hereafter propose to specification writing bodies in those fields.

III. A RE-EXAMINATION OF THE PROGRAM OF THE COUNCIL

E. L. Erickson:

The Bureau of Public Roads is very much interested in the work of the Column Research Council and it is a source of satisfaction to us to contribute toward the support of some of its projects.

The possible effect of residual stresses on the behavior of columns was first brought to our attention during the testing of four large columns at the University of Illinois during 1949 and 1950. The rather disappointing results of these tests were attributed to residual stresses in the materials. Because of this, we have followed the work at Lehigh University with considerable interest and we are pleased that this work has progressed to a point where it is now possible for Committee A to consider the inclusion of the effects of residual stresses in column formulas.

The stability of the top chords of pony trusses has always been a matter of considerable uncertainty. The work which is being carried on at Pennsylvania State University on the testing of bridge models is throwing light on this problem. The compression chords of these trusses appear to have greater lateral stability than has been realized before. Occasionally, members of Committee G meet at Pennsylvania State University to review the work which has been performed and to assist in the planning of future work.

The initial phases of the work at Cornell University on the strength of elastically restrained, eccentrically loaded columns have been completed and the work is described in a paper by Professors Bijlaard, Fisher, and Winter, presented to the American Society of Civil Engineers and published as Proceedings Separate No. 292. This paper, with its discussion and with a supplement by the authors will also be published in the forthcoming volume of Transactions. A supplementary phase of the project, dealing with the strength of two-flange, eccentrically loaded columns is now in progress.

We have mentioned only a few of the projects in which we have a particular interest, and we feel that considerable progress has been made in fields which have hitherto been overlooked. We hope the work of the Column Research Council will continue and that primary emphasis will be given to projects which have a direct practical application. In this connection, we recommend that all completed projects of the Council be summarized and that design formulas and criteria be tabulated for the benefit of engineers and their organizations. Along these lines, I believe that Mr. Van Eenam of my staff has a suggestion to offer concerning a matter which we believe deserves serious attention.

Neil Van Eenam:

The use of cover plates on beams and girders is a long established practice. Within limits, they provide an economical means of increasing the resisting moment of a section. At present, most specifications place no limit on the number and size of cover plates that may be used, the only penalty being that for using long rivets. They do require, however, that cover plates be of equal thickness or that the thickness diminish from the flange angles outward. Also, no plate is to be thicker than the flange angles.

When cover plates are made the full length of the girder, they receive their stress gradually. The rivets are required only to develop the increments of stress entering the plates. But when partial length plates are used, they receive at their ends all the accumulated stress that would otherwise have been built up gradually. We do not know in what manner the rivets at the ends distribute this initial load. It is probable that the end row of rivets carries the greatest stress and that the intensity decreases on each succeeding row until the initial force has been developed. After that, the remaining rivets have only to transfer the linear increments of stress into the cover plates.

The AREA Specifications require that when cover plates are used, at least one plate on each flange shall extend the full length of the girder. This is a very fortunate provision, because at the beginning of the second cover plate, the change in flange area is less abrupt and the initial force is considerably reduced. Under the AASHTO Specifications, on the other hand, the use of full length cover plates, on top or bottom, is not required when the top flange is to be covered with concrete. Since deck-type construction is very commonly used, many girders have fairly large partial length cover plates attached directly to the flange angles.

In the field of highway bridge construction, three-span continuous girders are frequently employed and considerable use is made of A-242 low-alloy steels. There is an incentive to limit the thickness of the metal to 3/4-inch and under, because with a guaranteed yield point of 50,000 psi., the AASHTO Specifications permit a basic unit tensile stress of 27,000 psi. on the net section. In this type of construction, partial length cover plates are generally used adjacent to the piers and some bridge engineers proportion the sections so that plates are also necessary in the regions of positive moment. The rivets used are generally of structural rivet steel, conforming to ASTM A-141.

The tests of rolled beams with partial length cover plates conducted by Professor W.M. Wilson and reported in University of Illinois Bulletin 377, while limited in scope, indicate that the conditions at the ends of these plates deserve careful attention. The present AASHTO Specifications

require that any flange plates shall extend at least one foot beyond the theoretical end and that there shall be a sufficient number of rivets at each end of each plate to develop its full stress value before the end of the next outside plate is reached. This requirement may usually be met without difficulty by using a uniform spacing of rivets with a fairly large pitch over the length of the plate from its end to the beginning of the next outside plate. But whether this meets the needs is questionable. The computed values of the initial stresses in the cover plates are usually fairly high, while the linear increments of stress from the external shear are small. This suggests that a greater number of rivets should be provided at the ends in order to avoid high local stresses.

In view of this, the recommendation has sometimes been made that cover plates be ended at sections where the maximum stress does not exceed 80 percent of the allowable. The AREA is considering, at the present time, a revision of its specification which would require that partial length cover plates extend far enough to develop the capacity of each plate beyond the theoretical end. It proposes also to limit the gross cover plate area to 70 percent of the gross flange area. Although these two proposals aim to overcome the same objectionable features, they may lead in some cases to rather different results.

In our opinion, reliable test data are necessary before a satisfactory solution of the problem can be found. It is known that the treatment given in current specifications is not adequate. But the proposals now being considered for overcoming the objectionable features are not based on tests and the beneficial effects to be expected from either one will be uncertain. We believe that a program of tests will be necessary to throw more light on the problem and recommend that Column Research Council give consideration to undertaking the program.

H.H. Bleich:

The theme of this session is the "Reexamination of the program of the Council" and it seems to the speaker that one of the items which require a careful re-examination is the question of making the best use of the considerable amount of theoretical results in the field which are now available. It is intended that these results be processed into design specification, a task assigned to the Committee on Recommended Practice.

Two of the speakers of our 1954 technical session, Drs. Kavanagh and Winter have pleaded against insistence on excessive simplicity in formulating these specifications, because such simplicity means too frequently that the resulting structures will sometimes be overdesigned, and sometimes have too low a safety factor. Attention was drawn to some European specifications which have become extremely lengthy and detailed, and it

was suggested that new specifications proposed by the Council be intermediate in complexity between present American and European specifications.

The argument for refinement of present specifications is very powerful. The AISC specifications, except for revisions, have been conceived at a time when the state of the "art" was much more elementary, and there is simply no way of condensing the knowledge now available into such simple terms. Unfortunately, there is also a valid argument against refined specifications written in theoretical verbiage. There is a large number of men in industry whose education was obtained many years ago, and stopped at the B.S. The majority of these men are unable (or possibly unwilling) to use a more advanced type of specification. For a variety of reasons it is hardly practical to retire all such men and some way must be devised to let them continue to work on the design of the more routine type of structures which is all with which this type of man ought to be entrusted.

It seems rather unreasonable to penalize the public and those engineers who know better by forcing them to use specifications written for use by the low-standard men. It is the speaker's suggestion to resolve the problem by the use of a "double standard" in the specifications. It is suggested to provide: 1. A set of simple rules for routine cases, essentially like the present AISC specifications, except that explanations should be provided how these rules were derived and giving a clue to their inherent limitations. (The lack of knowledge of such limitation is a major cause for mis-use of present specifications). 2. A set of advanced specifications allowing the highly trained engineer to use his better knowledge for the public benefit. The use of the advanced specification should be permissive, and they would be compulsory whenever the importance of a structure warranted a refined design.

The adoption of such "double-standards" would alleviate the present situation in which available knowledge cannot be used. The present arrangement is equivalent to making a requirement prohibiting the analysis of statically indeterminate structures by moment distribution and prescribing that in all cases simple moment coefficients -- like $wl^2/10$ and $wl^2/16$ -- must be used. While such simple methods have their place in simple designs, no one would tolerate their use as binding laws.