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Future connection research problems, July 1972

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Beam-to-Column Connections

FUTURE CONNECTION RESEARCH PROBLEMS

by

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TABLE OF CONTENTS

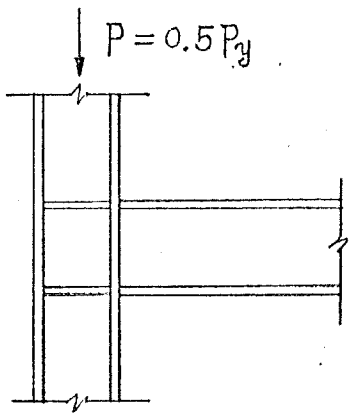
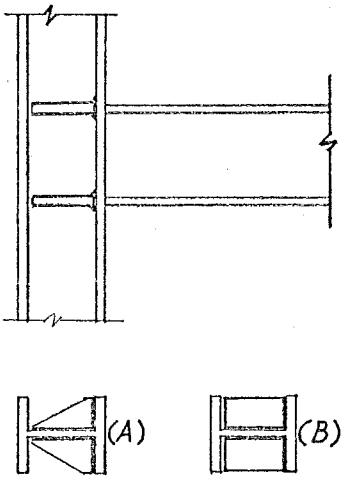
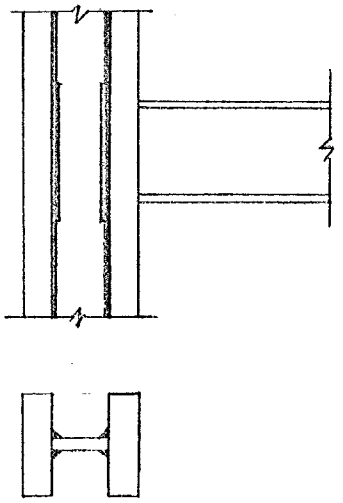
1. INTRODUCTION

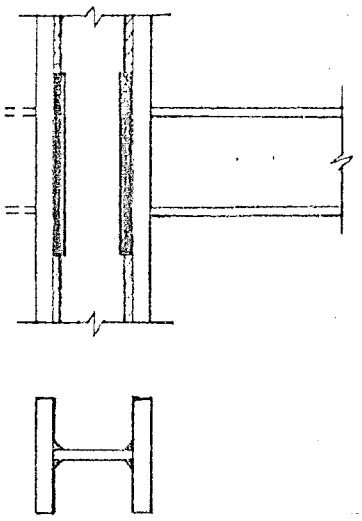
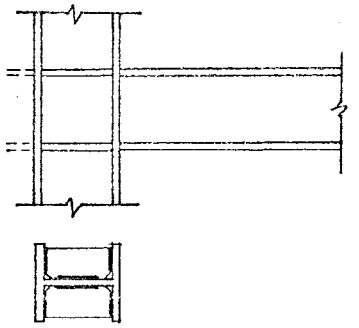
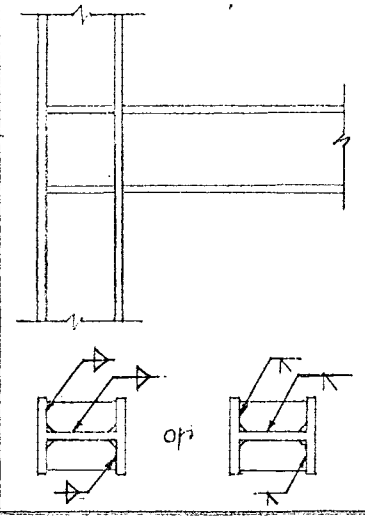
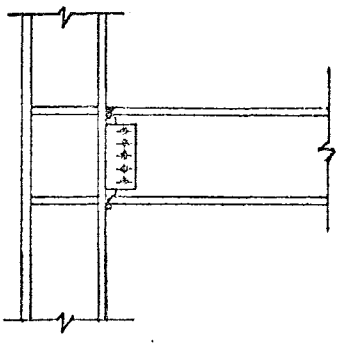
This report contains a compilation of many of the major problems in the design of beam-to-column connections which have been used extensively in steel building frames. The various types of connections included herein were discussed at a WRC Task Group meeting held previously (1). Those connections are considered to be of particular interest to designers, and are in need of research work.

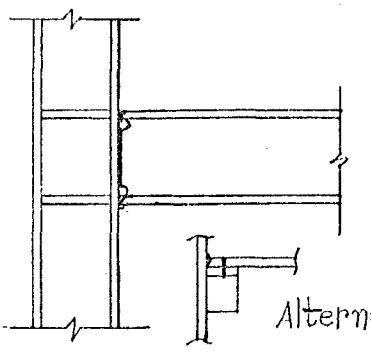
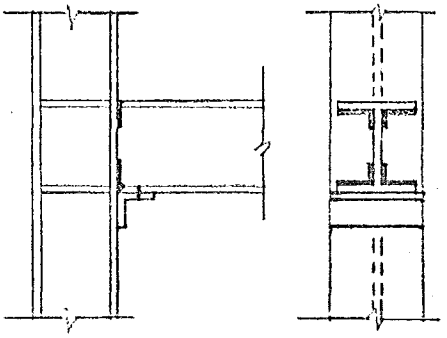
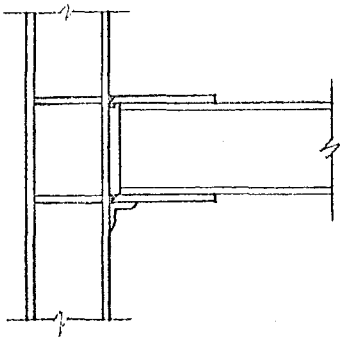
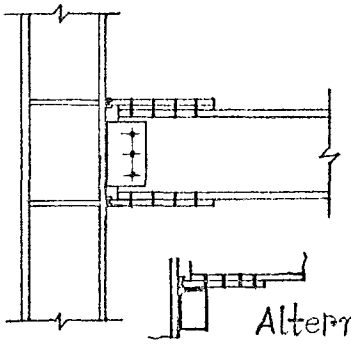
Currently, a research program on beam-to-column connections is under way at Lehigh University under the guidance of the Welding Research Council (see Appendix 3 for Task Group Roster). The objective of the investigation is to develop design procedures for safe, efficient, and economical beam-to-column connections. This report is prepared as a guide for the direction of research work to achieve that goal.

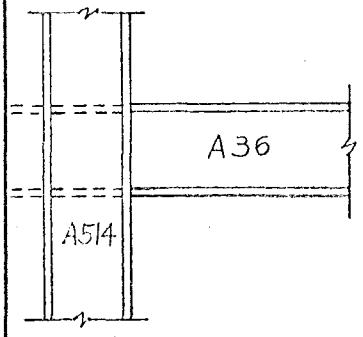
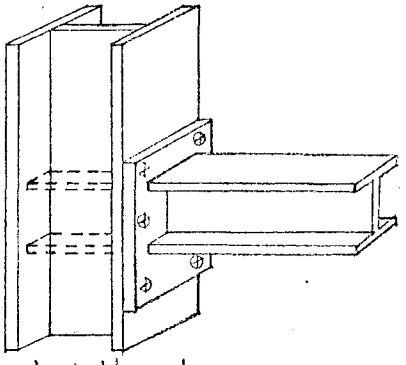
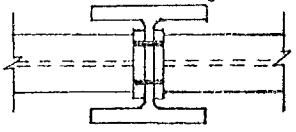
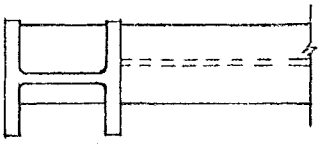
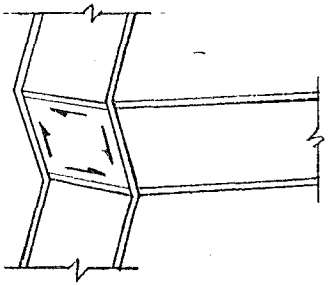
The arrangement of the types of connections in this report is according to the classification for connections in Refs. 2 and 3. The graphical presentation and justification for each problem help pinpoint the future research needs. The current research under way for certain problems is also cited to eliminate the unnecessary duplication of research in beam-to-column connections.

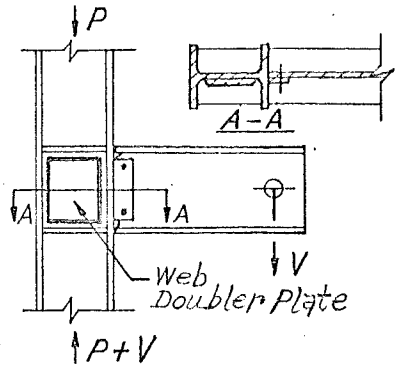
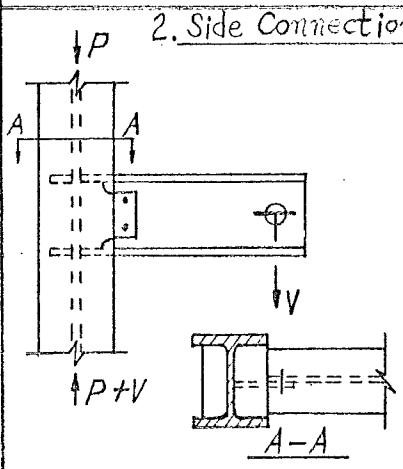
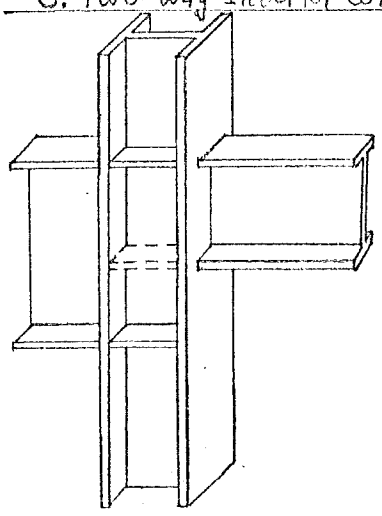
Comments of the WRC Task Group members concerning the priority sequence, along with the Lehigh staff recommendation, are summarized in Appendix 1. The connection tests corresponding to each suggested problem are also indicated in the tabulation. Appendix 2 presents the current research program which is being carried out at Lehigh University. The outline of work and status for each phase and the reports completed to data are included.

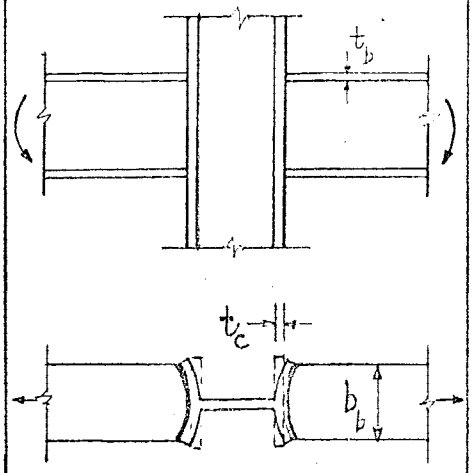
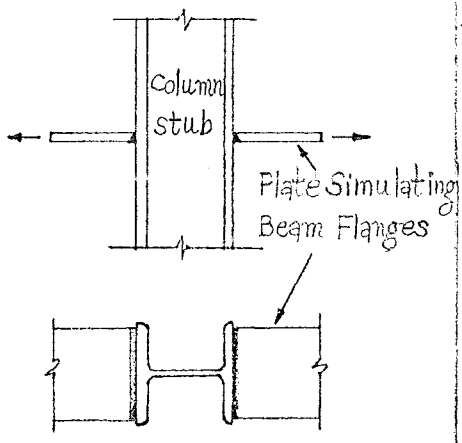
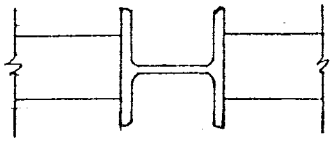
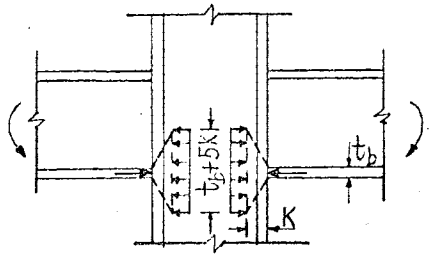
No.	Problem	Reference	Current Research
	1. Side Connections : Flange-connected		
1.1	 **Problem :** Determine the influence of the axial load on the behavior of connections in shear, including strainhardening effect. **Justification :** Potential economy through utilization of reserve strength in shear.	5 20	4:5.8.3(12) Lehigh Phases 5 and 6
1.2	 **Problem:** Connections with column-web stiffeners not welded to the column flange opposite the flange to which the beam is connected. **Justification :** Save welding, material and fitting time.	1 (1) 14 (XI A)	
1.3	 **Problem :** Columns with very thick flanges and fairly shallow web depths. (How large should the column web-to-flange welds be and can fillet welds be used instead of groove welds ?) **Justification :** Fabrication economy.	1 (2) 14 (III A)	

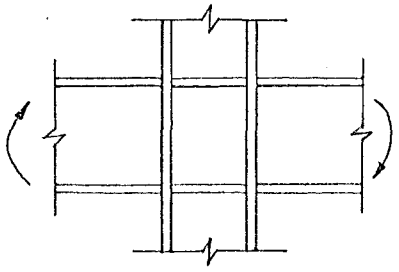
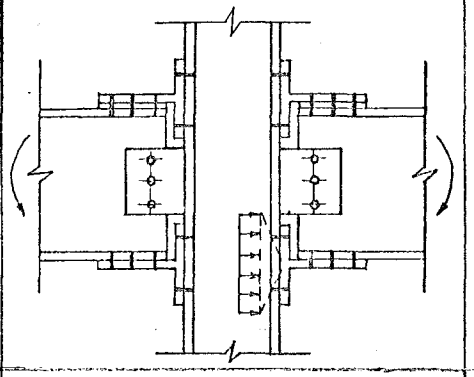
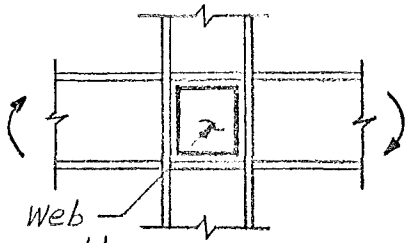
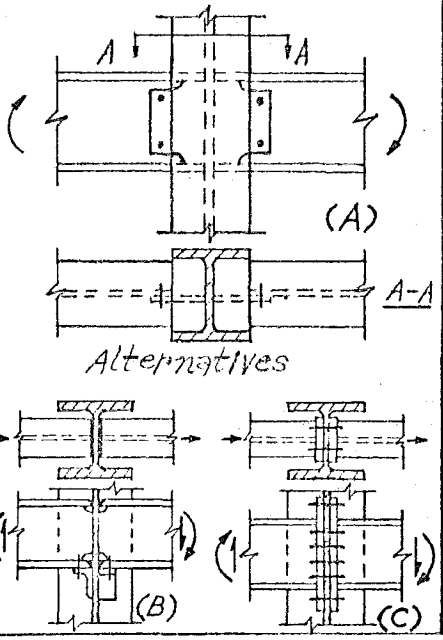
No.	Problem	Reference	Current Research
1.4	 **Problem:** Required amount of column web-flange weld in panel zone. **Justification:** Economy through decreased edge preparation and decreased amount of welding. **Note:** Applies to two-way interior connections.	1 (8) 14 (IV C)	
1.5A	 **Problem:** Stiffener requirements. **Justification:** Safety and economy.	14 (V A) 16	
1.5B	 **Problem:** Weld requirements for stiffeners; fillet or groove welds. (Can fillet welds be substituted for groove welds?) **Justification:** Economy of welding and, in some cases, of edge preparation.	1 (12) 14 (V A) 16	
1.6	 **Problem:** Flange-welded web-bolded connections. **Justification:** Save field welding on the web.	1 (3) 14 (II A) (II B 1,2,3) (VI A 2) 8 (66-30) 16, 17 18	4:5.8.3 (12) Lehigh Phase 10

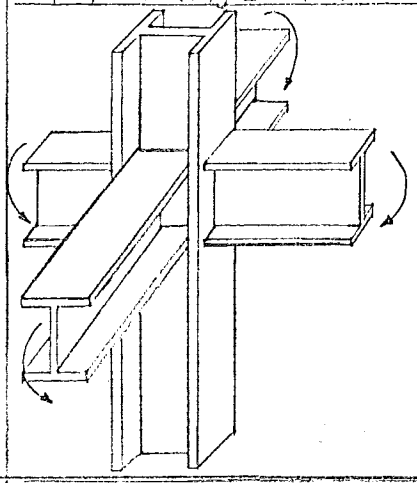
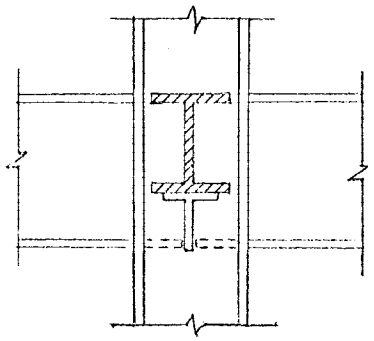
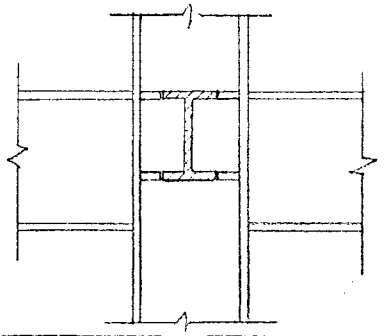
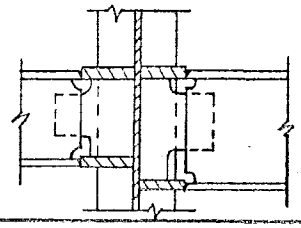
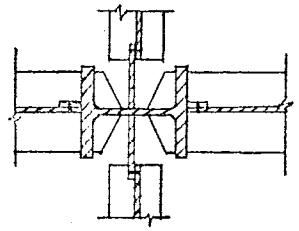
No.	Problem	Reference	Current Research
1.7	 **Problem:** Flange-welded connections. (Is it possible to develop predictable moment without any attachment to web ?) **Justification:** Eliminate costs of vertical field attachment.	14(IIB-1) 16, 17 18	4:5.8.3(12) Lehigh Phase 10
1.8	 **Problem:** How much weld is needed to develop Mp ? **Justification:** Reduce costs of vertical field attachment.		
1.9A	 **Problem:** Welded top and bottom moment plate connections. **Justification:** Economy in certain cases where moment of less than Mp is desired.	1 (13) 6 8(66-30) (67-51) Berkeley 14(VIA2)	
1.9B	 **Problem:** Bolted top and bottom moment plate connections. **Justification:** Economy due to the use of high-strength bolts and the saving of field welding on the web.	1 (13) 7 (60-8) 8 (66-30) (67-51) 14(VIA1,2) 16, 17 19	4:5.8.3(12) Lehigh Phase 11

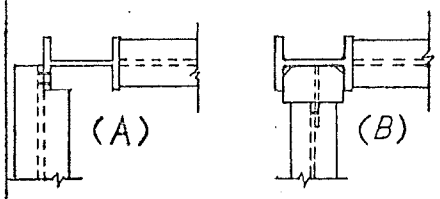
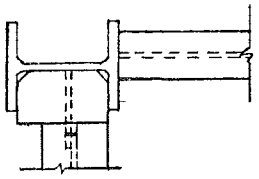
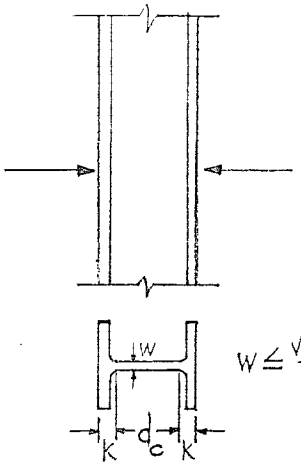
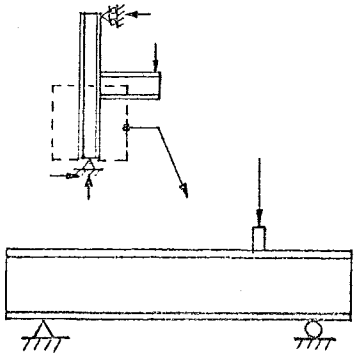
No.	Problem		Reference	Current Research
1.10	 Also other types	**Problem:** Structural carbon steel beam-to-higher strength steel column connections. **Justification:** Possible application to multistory structures. Economical use of higher strength steel.	1 (14) 14 (VII) 15	
1.11	 Also other types, 	**Problem:** End plate connections. Need for stiffening. **Justification:** Erection economy when local conditions make field welding uneconomical. **Note:** See 3.9	1 (15) 7 (60-8) (62-15) (63-7, 65-14) Cornell, 8 (67-16) Berkeley 14 (VC 2) (XIII A, B, C) 15	
1.12		**Problem:** Eccentricity of beam-column webs. **Justification:** Lack of knowledge of connection behavior leads to designs that are either underdesigned or over conservative.	1 (7) 14 (XII.)	
1.13		**Problem:** Analysis of effect on structure of omitting shear stiffening. **Justification:** Present method of frame analysis does not consider panel zone deformation.	14 (IA, B, C, D) 5 20	4; 5.8.3 (12) Lehigh Phase 6
1.13A		Inelastic tension-field analysis		Lehigh Phase 6

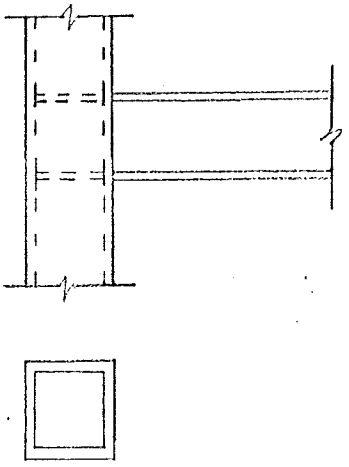
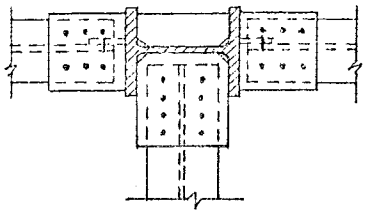
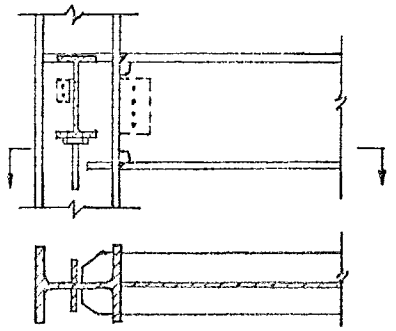
No.	Problem	Reference	Current Research
1.14	 **Problem:** Panel zone stiffening by adding a web doubler plate. **Justification:** Verification of present method of frame analysis (See 3.8)		4:5.8.3(12) Lehigh Phase 15
2.1	2. Side Connections: Web-Connected (welded or bolted)  **Problem:** Behavior of beam-to-column web connections is unknown. **Justification:** Logical design procedure should lead to greater economy. **Note:** Also applies to two-way interior connections. (See 3.9)	1 (9) 8 (67-51) BerKeley 14 (II A,C) (III B) (V B,C1) 19	4:5.8.3(12) Lehigh Phase 14
3.1	3. Two-Way Interior Connections  **Problem:** Out-of-line stiffeners. **Justification:** Save welding of extra stiffener within panel zone.	1 (4) 14 (X A) 15	4:5.8.3(12) Lehigh phase 8

No.	Problem	Reference	Current Research
3.2	 **Problem:** High strength steel beam tension flange performance. Determine the influence of parameters such as beam flange width to column flange width, column flange width to thickness, yield stress level on the strength of tension region, i.e., check $t_c^2 = \frac{b_b t_b}{2c_1}\left(1.25\frac{\sigma_{yb}}{\sigma_{yc}} - \frac{m}{b_b}\right)$ Also determine weld requirement. **Justification:** Safety and economy.	1(16) 9 14(IV A) (VII)	
3.2A	Beam end fabrication problems.		
3.3	 **Problem:** High strength steel tension region criterion. check resistance to fracture. Determine the influence of parameters on the behavior of tension region of connections. **Justification:** Present rule does not assure maximum economy and safety.	9 15	
3.4	 **Problem:** Beam width effect, $b_b \ll b_c$. **Justification:** Check the effect on connection performance when $b_b \ll b_c$. Assure needed safety.	14(VI A2)	
3.5	 **Problem:** Column compression stiffener requirements. **Justification:** Economy possible through elimination of stiffeners.	9 14(IV B)	

No.	Problem		Reference	Current Research
3.6		Problem: Horizontal stiffener requirements under unbalanced loads. Justification: Possible economy.		
3.7		Problem: Horizontal stiffener requirements for T-stub bolted connections. Justification: Possible economy.		
3.8		Problem: Panel zone stiffening by adding a web doubler plate. Justification: Verification of present method of frame analysis		
3.9		Problem: Beam-to-column web connections Justification: Safety and economy.	1 (9) 14 (III B) (V B, C1)	

No.	Problem	Reference	Current Research
	4. Four-Way Interior Connections		
4.1	 **Problem:** 2 – and 4 – way column connection with concurrent moments. **Justification:** Possible stiffening action provided by the two beams framing onto the column web may enhance connection performance.	1 (5) 9 14(IX)	
4.2	 **Problem:** Connection to column of different depth beams at right angles with tee seat at bottom of shallower beam. **Justification:** Elimination of one or both stiffeners.	1 (10)	
4.3	 **Problem:** Stiffeners eccentric to beam flanges. **Justification:** Possible strengthening effect of eccentric stiffeners.	1 (11) 14 (XA)	
4.4	 **Problem:** Eccentric stiffeneps for beams of different depth connected to the web of column. **Justification:** Economy	14 (X B)	
4.5	 **Problem:** Stiffeners less than one-half the depth of column. **Justification:** Present design rule is impractical.	14 (XI B)	

No.	Problem		Reference	Current Research
	5. Corner Connections			
5.1		**Problem:** Corner column connections. **Justification:** Lack of knowledge of connection behavior.	1 (6) 14 (VIII)	
5.2		**Problem:** Eccentricity of beam-column webs in corner connections. **Justification:** Logical design rule should achieve economy.	14 (VIII) (XII)	
	6. Column Web in Compression Region			
6.1	 $w \leq \frac{\sqrt{\sigma_y}\, d_c}{180}$	**Problem:** Limiting slenderness ratio of column web (d_c/w) in beam-to-column connections. **Justification:** Complete absence of data for higher strength steels. Potential economy through omitting stiffeners.	10 21	4:5.8.3 (12) Lehigh Phase 7 4:5.8.3 (31) Waterloo, Canada
6.2		**Problem:** Panel zone shear force caused by unbalanced moments. **Justification:** Verification of present design method. Economy through omitting stiffeners.		

No.	Problem		Reference	Current Research
7.1	7. Box Columns 	Problem: Connection of beam to box column. Justification: Determine economical stiffener requirements.	1 15	Deferred (Ref. 1)
8.1	8. Three-Way Connections 	Problem: Stiffener requirements in three-way connections. Justification: Economy resulting from design rule considering the unsymmetrical column stiffening action	14 (VIII)	
8.2		Problem: Stiffeners less than one-half the depth of column. Justification: Present design rule is impractical.	14 (XI B)	
9	Resistance to Fracture	Check appropriate phases	15	
10	Associated Bracing Connections	To be examined	15	
11	Influence of Cladding	To be examined	15	

3. APPENDICES

APPENDIX 1: PRIORITY SEQUENCE

The priority sequence suggested by the members of the WRC Task Group on Beam-to-Column Connections is shown as follows:

Priority / Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Pinkham [11]	1.6	2.1	1.3	1.4	3.1	4.3	1.5	1.2	1.12	4.2	5.1	4.1	1.10	3.2	1.11	
Bertero [12]	2.1	4.1	1.6	3.1	4.3	1.10										
Diefendorf [13]	1.6	1.9	2.1	1.11	4.1	1.4	1.3	5.1	4.2	1.5	1.2	3.1	4.3	1.12	1.10	3.2
Edwards [14]	1.13	1.6	1.9	3.2	3.5	2.1	1.5	1.3	1.4	8.1	1.11	3.1	4.3	4.1	5.1	1.10

Lehigh Staff Recommendation:

Priority	Problem	Test	Ref.
Group A	1.6 Flange-welded web-bolted connections.	C1,C2,C3	16,17
	1.7 Flange-welded connections.	C4,C5	
	1.9B Bolted top and bottom moment plate connections.	C6,C7,C8 C9	
	1.5A Stiffener requirements for beam-to-column connections.	C-series	
	1.5B Weld requirements for stiffeners, fillet or groove welds. (Can fillet welds be substituted for groove welds)?	C1,C6,C7 C10	
Group B	2.1 Beam-to-column web connections.		
	1.14 Panel zone stiffening by adding a web doubler plate for beam-to-column flange connections.		

Priority	Problem	Test	Ref.
Group C	3.1 Out-of-line stiffeners.		
Group D	1.3 Columns with very thick flanges and fairly shallow web depths. (How large should the column web-to-flange welds be and can fillet welds be used instead of groove welds)? 1.4 Required amount of column web-flange weld in panel zone. 4.1 Two- and four-way column connection with concurrent moments.		
Group E	1.11 End plate connections. Need for stiffening.		

APPENDIX 2: CURRENT PROGRAM: BEAM-TO-COLUMN CONNECTIONS

Statement of Problem:

Insufficient information is available on the post-yield behavior of beam-to-column connections subjected to column axial forces and transverse shear forces from the beam moments. Further data is needed on reserve strength due to strain hardening.

Justification:

Eliminate stiffeners presently required or specify smaller stiffeners than otherwise needed.

Outline of Work and Status:

1. Pilot tests on small welded (stiffened) connections cut from old test frames. (complete) 333.2
2. Theoretical analysis of column load-moment interaction. (deferred)
3. Study of U.S., Japanese, and British test data on beam-to-column connections. (complete) 333.7
4. Preparation of design table for connection shear stiffening requirements using results of (2) above. (deferred)
5. Major test on a large connection with no shear stiffening. (complete) 333.9 (Prob. 1.1)
6. Analysis of effect on structure of omitting shear stiffening. (current) 333.16 (Probs. 1.1, 1.13, 1.13A)
7. Tests to check column web buckling formula especially for higher strength steels. (complete) 333.10, 333.14 (Prob. 6.1)

8. Study of stiffening requirements for beams of different depth on opposite sides of interior connection. (deferred) (Prob. 3.1)
9. Basic study of plastic deformation and strain hardening in a thick plate subject to high shear stress. (deferred)
10. Flange-welded web-bolted connections. (current) 333.15, 333.17 (Probs. 1.6, 1.7)
11. Bolted top and bottom plate connections. (current) 333.15, 333.17 (Prob. 1.9B)
12. Study of web stiffeners. (current)
13. Study of connection behavior in related tests. (current)
14. Beam-to-column web connections (future) (Prob. 2.1)
15. Panel zone stiffening by adding a web doubler plate for beam-to-column flange connections. (future) (Prob. 1.14)

APPENDIX 3: WELDING RESEARCH COUNCIL TASK GROUP ON BEAM-TO-COLUMN CONNECTIONS

(AISI Project 137, Lehigh University Project 333)

John A. Gilligan, Chairman, U. S. Steel Corporation

Victor V. Bertero, University of California

Omer W. Blodgett, Lincoln Electric Company

Hubert C. Crick, Mosher Steel Company

Carson F. Diefenderfer, Bethlehem Steel Corporation

Norman W. Edwards, Pittsburgh-Des Moines Steel Company

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Harold J. Engstrom, Jr., AFCO Steel Company

Theodore R. Higgins, American Institute of Steel Construction

Ira M. Hooper, Seelye-Stevenson-Value-Knecht

Carl L. Kreidler, Bethlehem Fabricators, Inc.

Hugh A. Krentz, Canadian Institute of Steel Construction

William A. Milek, Jr., American Institute of Steel Construction

Clarkson W. Pinkham, S. B. Barnes and Associates

Arch N. Sherbourne, University of Waterloo

Vincent R. Cartelli, Severud-Perrone-Sturm-Bandel

Charles F. Larson, Secretary, Welding Research Council

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