Summary report, Lehigh University, (1958)

Fritz Lab
WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS

INTERIM REPORT NO. 40

SUMMARY REPORT 1958

by

Project Staff

September 1958

Fritz Engineering Laboratory Report No 205.63
Welded Continuous Frames and Their Components

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SUMMARY REPORT - 1958

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(Not for publication)

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Bureau of Yards and Docks

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September 1958

Fritz Engineering Laboratory
LEHIGH UNIVERSITY
Bethlehem, Pennsylvania

Fritz Laboratory Report No. 205,63
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Project Objectives

The original objectives, approved at the March, 1950, meeting of the Lehigh Project Subcommittee are as follows:

1. To determine the behavior of steel beams, columns and continuous welded connections with emphasis on plastic behavior, and to develop theories to predict such behavior.

2. To determine how to proportion various types of welded continuous frames to develop the most balanced resistance in the plastic range so that the greatest possible collapse load will be reached.

3. To determine procedures of analysis that will enable one to calculate the collapse loads of welded continuous frames and to verify the analysis by suitable tests.

4. To determine procedures of analysis that will enable one to calculate the elastic and permanent deformations in welded continuous frames in the range intermediate between elastic limit and collapse load.

5. To explore limitations in the application of plastic range design over and above deformation limitations, namely, fatigue, local buckling, lateral buckling, etc.

6. To develop practical design procedures for the utilization of reserve plastic strength in the design of continuous welded frames.

In brief, then, the program consists of:

1. Column, Beam, and Connection Studies (Frame Components)

2. Frame Studies (Integral Behavior)

3. Practical Applications (Methods of analysis and design with due regard to limitations such as fatigue, deflections, local buckling, etc.).
### Welded Continuous Frames and Their Components

Outline of Current Program (1958 - 1959)

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## Welded Continuous Frames and Their Components
### Work Done (1957 - 1958)

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<td>205-IV</td>
<td>Design Manual and Specifications</td>
<td>Review AISC Manuscript</td>
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| 205-V | Design Procedures | Two reports:  
1. Pinned base frames (PR 24)  
2. Lean-to frames (PR 28)  
Work on:  
1. Fixed base frames  
2. Saw-tooth frames |
| 205-IX | Regional and National Conferences | Marquette University  
University of Wisconsin  
University of Wyoming  
ASCE Annual Meeting 1957 |
| II. STUDIES OF STRUCTURES | | |
| 205D-I | Portal Frames - Vertical load | Completed a draft of the report on first two frames tests (supplement to PR 27)  
Completed the report on Summer Conference Test frame (PR 30) |
<p>| 205D-III | Industrial Frames | Completed a draft of the report on Spring Conference test frame |
| 273-I | Multi-Story Frames Preliminary Studies | Completed literature survey (Interim Report 42) |</p>
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<td>Completed a draft of interim design guide and report on confirming tests.</td>
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<td>268-I</td>
<td>Rotation Capacity Beams Single-span frames</td>
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<td>Solution completed in Driscoll's dissertation</td>
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EVALUATION, ANALYSIS, AND DESIGN, PHASE III

"COMMENTARY" ON PLASTIC DESIGN

Statement of Problem:

The evaluation of a considerable amount of research has demonstrated the applicability of plastic analysis to structural design. As a justification for this design method, a report will be prepared in which the results of analysis and tests will be summarized. The results of studies of secondary design considerations will be presented. In some cases the more "exact" solutions will be simplified such that they are appropriate for design use.

Such a report would serve as a background for a practical design manual, a manual that is now being prepared by the American Institute of Steel Construction.

Outline of Work:

1. Preparation of reports stating the design problems, the applicable results of research, the necessary additional research, suggested rules of practice. (completed by Interim Report No. 26 and Progress Report 18)

2. Extension of item (1) and completion of Progress Report to Lehigh Project Committee (WRC)

3. Following approval by WRC Committee, report to be submitted to ASCE Committee on Plasticity Related to Design. The report would then be revised (as needed) by both the WRC and the ASCE Committees and issued as a joint WRC-ASCE report.

4. Revision from time to time as new information becomes available.

Current Program:

Part I (Chapters 1 to 5) has been completed through item (3).

Part II (Chapter 6: Additional Design Considerations) has reached the stage of item (2).

Part III (Chapters 7 and 8: Connections and Deflections), rough drafts have been completed.
Statement of Problem:

There is a need to illustrate the use of plastic design through the inclusion in reports of specific design examples; the results may be compared with those obtained by the conventional elastic methods.

While the basic theorems of plastic analysis and design are sufficiently general to enable one to obtain the solution to most structural problems, it is felt that further study and development will reveal techniques that will materially reduce the design time.

Outline of Work:

1. A review of the literature on methods of analysis with particular reference to minimum weight design.

2. A study of the basic behavior of typical structures at failure noting the transfer of resistance from one part of the structure to the other.

3. Explore new methods of solution to certain of these problem types (e.g. gable frames, tier buildings, etc.)

4. Formulation of rules for the selection of more economical (least weight) combination of member sizes in a structure.

5. Preparation of reports on the above.

Current Program:

Two reports on chart solution have been completed (Progress Reports 24 and 28). They cover the design procedure for pinned base gable frames and lean-to type frames. The current work is to complete two reports dealing with the design of gable frames with fixed bases and the design of frames for distributed wind load.

Work has been started to develop design charts for sawtooth frames by using the procedure indicated in Progress Report 24.
Statement of Problem:

Although some methods of analysis have been rather widely publicized (such as the semi-graphical "equilibrium method") there is need for further explanation and illustration of some of the more recent methods.

Some methods are more suitable to one type of structure than to another. Applicability of the various methods should be studied. Also, certain simplifications may be made to existing methods of analysis, rendering them more suitable for design use.

As more is learned about the plastic behavior of structures and as additional types of structures are encountered, new methods of analysis may be required.

Outline of Work:

1. Summarize existing methods of analyzing structures for ultimate strength.


4. Develop analysis procedures for new structural problems encountered.

Current Work:

The current work is to complete Item (2).

Work will then begin on Item (3) (Project 273)
STUDIES OF COMPONENTS

SIMPLE COLUMNS WITH THRUST AND MOMENT

Statement of Problem:

As a prerequisite to the determination of the strength of members as they are found in building structures, it is first of all necessary to be able to define the behavior of a given member with given end conditions subjected to given conditions of loading. From this information interaction curves of maximum carrying capacity can be obtained. These could then be used in the design of members subjected to comparable loadings as well as form a basis for further developments toward the solution of the more general problems.

Outline of Work:

1. A review of the various classical methods of determining the ultimate carrying capacity of beam-columns.

2. For a member subjected to axial thrust and equal end-moments, which result in single curvature deformations; the development of ultimate strength interaction curves for a typical wide-flange shape neglecting the influence of residual stress.

3. An extension of item 2 to include the influence of a symmetrical, cooling type of residual stress pattern.

4. An extension of items 2 and 3 for the following conditions of loading:
   
   a. Axial thrust plus end-moment applied only at one end of the member,
   
   b. axial thrust plus equal end moments resulting in double curvature deformation,
   
   c. axial thrust plus moment applied at one end of a member while the other end is held fixed, and
   
   d. axial thrust plus end moments of unequal magnitude (\( M_{\text{BOTTOM}}/M_{\text{TOP}} = 0.5 \) and perhaps one added moment gradient if necessary to permit the construction of moment gradient, the moment at the top of the columns and the slenderness-ratio.)

5. Representation of the interaction curves of 2, 3, and 4 in analytical form for use in design.

6. Carry out a series of tests on as-delivered wide flange members to confirm the findings of the analytical study and to determine experimentally the end rotation capacity of the test specimens.
7. Determination of analytical procedures to compute the rotation capacity and the influence of sideway on the column strength.

8. Preparation of reports.

Current Program:

The current work is aimed at completing parts 4c, 4d, 6, 7 and 8.
STUDIES OF COMPONENTS

INELASTIC LATERAL TORSIONAL BUCKLING

Statement of Problem:

It has been observed that as a wide-flange beam-column is bent about its principal axis the strength as predicted from a consideration of the bending stiffness of the member about this axis is never reached. Prior to the attainment of the predicted load the member laterally bends and twists.

Since the most economical placement of material in a cross-section is the one that provides the greater bending stiffness in the direction of the anticipated greater bending moment, there will always be a difference in bending stiffness about each of the principal axes of the member; therefore, a possibility of lateral-torsional buckling.

A solution to this problem is needed to be able to predict the true strength of WF members bent about their major axis. The solution may also prove valuable in the determination of laterally unsupported length for lateral bracing requirements.

Outline of Work:

1. Review of the literature on this type of failure.
2. Develop a method of solution to the problem assuming that the member deforms in single curvature.
3. Establish "bending stiffness-axial load-curvature" relationships (graphical) about each principal axis. Assume annealed WF material.
4. Same as 3 with as-delivered member (idealized cooling residual stress pattern).
5. Develop interaction curves to show the seriousness of this type of failure. Comparison with previous work neglecting this factor.
6. Extension of work to include bi-axial loading problem (see Phase III).
7. Preparation of reports.

Current Program:

A report is presently under preparation, summarizing the solutions to the first five phases above.
Influence of Shear on Plastic Moment

Statement of Problem:

In general even in "Plastic Design" shearing forces are relatively small and do not govern a design. Their influence on the plastic moment is simply neglected. In special cases, however, high shearing stresses may lead to a reduction of the plastic moment. Such effects were previously observed in tests and also investigated theoretically. Nevertheless a systematic study was desirable to properly evaluate these effects.

Outline of Work:

Controlled tests on 5 specimens (12WF27) with different ratios of moment to shear were conducted. A parallel theoretical study of the problem was done. These and results available in the literature will be evaluated as to their design implications.

Current Program:

The test program is completed. A report on the work and the findings is pending.
HAUNCHED CONNECTIONS

Statement of Problem:* 

Since there are several reasons for the use of haunched welded connections in structures proportioned by the plastic method, it is necessary to have a simple yet accurate method of proportioning such haunches. The method should be such that it would fit into the philosophy of plastic design.

A design procedure should be developed which will assure the lateral stability of the sloping flange when the structure has reached its ultimate load.

Since it was thought necessary to maintain the haunch in an elastic state all previous research has followed that path. However, it is now thought that a fully plastic approach can now be used to proportion the haunch.

Outline of Work:

The project includes analytical studies confirmed by tests as follows:

1. Survey available methods of analysis.
2. Establish practical methods of proportioning haunched connections.
3. Outline a simple method of plastic analysis for bending and shear stresses within haunch.
4. Develop design procedure.
5. Select illustrative examples showing analysis and design for connections used in plastically designed frames.
6. Study optimum haunch lengths for plastically-designed frames.
7. Test several connections to correlate with theory.

Current Program:

Items 1 and 2 were completed and reported in Interim Report 37. Items 3, 4 and 5 were completed and reported in Interim Report 39. Experimental investigations in item 7 were completed; a report of test results is currently in preparation.

* See proposal December 1957 (Report No. 205.58)
Statement of Problem:

Multi-span frames by their greater degree of indeterminacy present more opportunity for increase in carrying capacity due to redistribution of moment. However, this might lead to limitations because of large rotation capacities required to allow the redistribution of moment. A test of a two-span frame with a large theoretical reserve due to redistribution of moment is desirable.

Outline of Work:

Work on this phase of the project would be carried out as follows:

1. A test was carried out in the 1956 AISC spring conference, on a two-span gabled frame of reasonably average proportions rather than one requiring a large theoretical reserve due to redistribution of moment.

2. Studies of proportions of two-span frames to select a suitable frame with a large effect due to redistribution of moment. The frame will have column sizes and lateral bracing spacings of extreme cases.

3. Design of test set-up.

4. Fabrication of frame with provisions made to measure "locked in" moments caused by accidental misalignments in fabrication.

5. Test of frame

6. Analysis and report

Current Program:

Report on 1956 spring conference frame will be completed. Work would then be started on item (2), following a study of possible extreme design for columns and lateral bracing spacings.
MODIFICATIONS AND SPECIAL TOPICS

LOCAL BUCKLING

Statement of Problem:

The importance of the local buckling problem has been emphasized by premature failure of tested continuous frames because of flange buckling.

The ultimate aim of the theoretical and experimental studies on this subject is to specify the dimensions of WF shapes such that they can safely be used in plastic design.

Outline of Work:

1. Review of available theories.
2. Tests to check the validity of the theory in the plastic range of steel.
3. On the basis of 2 select the valid theory or if possible propose a new theory.
4. Tests on WF shapes subjected to axial compression and pure moment.
5. Report
6. Summarize in a report available results of test on WF shapes subjected to moment gradient.

Current Program:

Parts 1 to 5 are completed. No work on part 6 has yet been started.
LATERAL BUCKLING

Statement of Problem:

One of the basic assumptions made in designing a structure for ultimate strength by plastic design methods is that a "plastic" hinge can be formed. That is, that the section is capable of undergoing large rotations within a limited region so that the moments may be redistributed to develop the full strength of the structure.

To accomplish these large rotations, provisions must be made to prevent the member from failing prematurely by lateral buckling. The general purpose of this project is to establish a criterion for the lateral buckling of members in the region where part of the member has undergone some inelastic deformation.

Outline of Work:

1. Preliminary tests on fix-ended WF beams under constant moment.
2. Analytical study for comparison with part (1).
3. Extension of analytical study to cases of:
   (a) Varying moment gradient
   (b) Varying end conditions
4. Analytical study on the post-buckling strength of the beams for the different cases.
5. Confirmatory tests under various conditions.

Current Program:

Parts 1 to 3 are completed. An additional 4 tests under varying moment gradients have been conducted. A report on these tests and tentative design recommendations is in progress.
MODIFICATIONS AND SPECIAL TOPICS
REPEATED LOADING: PART OF FRAME TEST

Statement of Problem:

Methods of "Plastic Analysis" consider in general only proportional loading, i.e. the ratios between all the loads of a given loading configuration stay constant up to the failure load. Actually cases of loading cycles, e.g. live loads in storage house, wind, cranaloads etc., are more common than such an idealized loading. Theoretically it can be shown that a limited number of loading cycles can produce successive plastic deformations such that the deflections increase with each cycle. A critical limit called the shake-down load is always smaller than the corresponding ultimate load for proportional loading, can be defined, above which the deflections never cease to increase.

Such theoretical predictions based on simplifying assumptions need some experimental check to evaluate their seriousness with respect to actual design.

Outline of Work:

Out of the approved program on full-scale frame tests, one frame will be subjected to cyclic loading prior to the failure test under proportional loading. Such a procedure will furnish the necessary results on the behavior of an actual frame under cyclic loading without requiring a special test.

Current Program:

Under consideration in connection with future frame tests,
MODIFICATIONS AND SPECIAL TOPICS

LATERAL BRACING

Statement of Problem:

The general purpose of this project is an application of the results obtained for the study of inelastic lateral buckling of members to the actual requirements and detailing of structures. Specifically the project is concerned, firstly, with the method of expressing the rotation requirements of a structure in a form from which its lateral buckling strength may be determined. Secondly, it is concerned with the effectiveness of various types of lateral support under various conditions.

Outline of Work:

1. Literature survey on previous research: summary of results, and comment on applicability to problem of lateral bracing requirements.

   Review of methods for expressing the necessary rotation capacity in the "hinge" region in view of the results obtained under Project 205E-V, 205C-III and VI, and 268.

2. Theoretical study for the purpose of developing necessary design criteria.

3. Analytical study of the effectiveness of various types of lateral bracing.

4. Experimental determination of the effectiveness of various types of lateral bracing.

Current Program:

In the next period, item 1 is expected to be completed and the work on item 2 will proceed. Possibility of experiments.
THE TANGENT MODULUS IN SHEAR

Statement of Problem:

Analysis of the local (plate) buckling problem shows that the buckling strength depends on the relationships between the increments of stresses and strains due to the deflection of the plate out of its plane*. For outstanding flanges the buckling strength depends to a large extent on the tangent shear modulus.

Thus, the important problem to be investigated is: The determination of the tangent modulus in shear of structural steel after it has been compressed into the plastic range.

Outline of Program:

1. Design a test set-up which will make it possible to compress and twist a tube successively and simultaneously.
2. Design a strain-gage which will measure the corresponding strains.
3. Perform tests
4. Compare test results with theoretical predictions.

Current Program:

Program is completed, the results have been summarized in a preliminary report. A final report is pending.

Presently available experimental results on the plastic behavior
of steel structures are exclusively restricted to structures fabricated with
solid sections. However, built-up members are very often used in practice,
especially in ship structures. Typical examples are deck girders with openings
in the corners and through the webs. A Vierendeel girder presents a further
typical example. The application of "Plastic Design" to such members offers
some new problems:

I. Survey on built-up members in actual applications, with special
   emphasis on ship structures.

II. Theoretical study of the problems in connections with "Plastic
    Design".

III. Proposal for exploratory testing.

III. Behavior as influenced by cut-outs in corner connections or webs.

IV. Stiffening requirements for deep webs as in deck girders.

V. Local stiffening requirements of flanges and corners.

V. Effective width of deck plate in buckled state after formation
   of plastic hinge in girder.

Current Program:

Phase I is completed and results are reported in PR No. 27
(Strength of Wide Flange Beams Under Combined Influence of Moment, Shear and
Axial Force).

Phase II and IV have been completed and results will be reported.

Phase III Problem is presently being studied in connection with
other research project on "Welded Plate Girder" (Project 251).

Phase V is a Ph.D. Dissertation (Buckling of Stiffened Panels in
Elastic and Strain Hardening Range) and reported in Interim Report 41.

*See proposal dated 24 January 1955, page 3, Report #205.68
Effect of Lateral Pressure on Inelastic Stability of Longitudinally Stiffened Plates (Ship Bottom Plating)

Statement of Problem:

The purpose of this program is to conduct an exploratory (pilot) experimental investigation of the effect of lateral loading on inelastic stability of longitudinally stiffened plates. Since this topic is particularly important for the design of ship hulls of longitudinal construction, proportions of the test specimens were specified as those of a typical ship bottom panel. Thus this program will consist in axial testing of three identical specimens (L/r = 54, b/t =60, A_{stiffener}/bt = 0.333) subjected to lateral loading equivalent to three levels of hydrostatic head: 0, 15 and 30 feet -- one specimen for one loading. The test set-up and dimensions of the specimens are shown in Figs 1 and 2. (Page 27 and 28). The lateral loading will be applied by means of a pneumatic system to avoid non-uniform pressure if a liquid system were used.

After this test series is completed, further investigation will include effects of varying L/r and A_{stiff}/bt-ratios.

Outline of Work:

1. Preliminary development of the specimens and test apparatus--subject for approval by the Department of the Navy.

2. Final design and fabrication of the test specimens and test apparatus.

3. Testing

4. Evaluation of the test data, report, possible recommendations for the design specifications.

5. Planning of further tests in view of the obtained results, and execution of these tests is considered as the next phase of this research.

Current Work:

Item 2 is being completed.
ROTATION CAPACITY REQUIREMENTS 268 I, II, III

Statement of Problem:

One of the basic assumptions involved in the computation of ultimate loads in plastic analysis is that the members and connections must have sufficient rotation capacity to allow all plastic hinges to develop. A general method for calculating the necessary rotation capacity is required. The problem is important because lack of adequate rotation capacity would be a serious limitation in the application of plastic analysis to structural design.

Outline of Work:

1. Develop analytical procedure for calculating deflection and rotation at plastic hinges at instant of formation of mechanism.

2. Analyze a number of structures by the method to determine the required rotation capacity of plastic hinges.

3. Compare the amounts of rotation capacity required with that attained in tests of similar structures or components.

4. Propose and conduct necessary tests to correlate with theory.

5. Evaluate problem of rotation capacity in the light of results obtained from analysis and tests.

6. Present practical method of calculating required rotation capacity of plastic hinges.

Current Program:

A Ph.D. Thesis has been written covering the cases of continuous beams, and single and multi-span gabled frames with pinned bases.

Reports for publication will be prepared with results of the Thesis. (Progress Report 29 and 31).

Future work will include fixed base frames.
STUDIES OF STRUCTURES

MULTI-STORY FRAMES, PHASE I AND II

Statement of Problem:

In order to apply plastic theory to the design of multi-story building frames, several problems should be studied in detail. Although the basic principles involved are the same as for single-story frames, design techniques and procedures are more complicated. Therefore, a possible simplification of the design procedure is needed. Frame stability and related column behavior in the plastic range are other important phases to be considered. Furthermore, rotation capacity requirements and deflection of such frames also need to be investigated.

The general purpose of this project is therefore to study different phases of the problems mentioned above in order to arrive at practical methods for the analysis and design of multi-story frames.

Outline of Work:

1. Extensive literature survey of existing methods of plastic analysis and theory of frame instability.
2. Studies of practical methods of analysis and design of such buildings.
3. Development of design procedure.
4. Studies of the behavior of continuous columns in the plastic range.
5. Studies of frame instability in the plastic range.
6. Tests of multi-story frames to study their plastic behavior and ultimate strength (Check the validity of simple plastic theory)
7. Tests of small scale frames to study the problem of frame instability and column behavior.

Current Work:

Item (1) has been completed (Interim Report 42). Work will then begin on items (2) and (3).

* See Proposal on page 29
In July, 1958, a proposal for a column test program was submitted to the Committee for approval. Since the returned postcards showed that the members of the Committee approved the program, work on the tests was started in August, 1958. The first test will be conducted in the last week of August. It is test number A-7 on Table 1.

To reacquaint the committee with the purpose and the scope of the test program, a brief recapitulation of the proposal is included here:

Objective of the proposed test series:

The objective of the 22 proposed tests is to determine the influence of

a) loading condition  
b) lateral bracing  
c) slenderness-ratio  
d) axial load  
e) end moment  
f) cross-sectional shape

on the behavior of beams columns, with special emphasis being placed on the observation of the plastic end-rotation capacity in the post-buckling stage. (There is no adequate theory available now to predict this rotation capacity, and previous experimental investigations were carried out at small axial loads).

Table 1 contains a summary of the proposed test program. The column material is as-rolled mild structural grade steel (A-7). The tests will be conducted such that a constant axial load is applied to the column first, and then it is subjected to independently applied increasing end-bending moments until the column fails. The ends of the column will be rotated until the load drops off, to measure the rotation capacity.

The tests will be conducted in the 5,000,000 pound testing machine at Fritz Laboratory. Specially fabricated beams will be connected to the columns of the testing machine to form a loading frame for the moment application.
<table>
<thead>
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<th>Loading Condition</th>
<th>Section</th>
<th>Length</th>
<th>Axial Load Ratio, P/Py</th>
<th>Expected Maximum Moment Mo/Mp</th>
<th>Slenderness Ratio l/γx (Length between knife edges)</th>
<th>Slenderness Ratio l/γy (Actual Column Length)</th>
<th>Lateral Bracing</th>
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<td>&quot;d&quot;</td>
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<td>----</td>
<td>59</td>
<td>96</td>
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<td>0.6</td>
<td>----</td>
<td>59</td>
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<td>145</td>
<td>*</td>
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<td>0.3</td>
<td>0.46</td>
<td>90</td>
<td>146</td>
<td>*</td>
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<td>*</td>
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<td>&quot;b&quot;</td>
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<td>0.3</td>
<td>0.75</td>
<td>90</td>
<td>146</td>
<td>*</td>
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</table>

Determined by the method outlined in the AISC Manual for Plastic Design in Steel.
Figure 1: TEST SET-UP

Scale: 1" = 20"

Sections A-A and B-B
BUILT-UP MEMBERS IN PLASTIC DESIGN, PHASE VI

$\frac{L}{r} = 54$, $\frac{b}{t} = 60$

$A_{\text{stiffener}}/bt = 0.333$

Fig. 2. SPECIMEN DATA

Scale: 1" = 1' - 0"
STUDIES OF STRUCTURES

Proposal for Multi-Story Frame Investigations
(Project 273)

by
Le-Wu Lu

To extend the application of the plastic theory to the analysis and design of tier building frames, numerous problems should be investigated. This proposal outlines some important phases which need to be considered in detail. The main emphasis of this project will be on the first of these problems (Design Procedure). Preliminary work will be concerned with the investigation of frames having 2 and 3 stories.

1. Design Procedure

Studies will be first directed toward the development of practical method of proportioning member sizes for such frames for the case with vertical load only. Procedure then will be developed for checking the member sizes thus selected against combined vertical and horizontal loads with a reduced load factor. A possible approach to develop such procedure is discussed in Interim Report 42. Simple plastic theory will be used throughout and frame will be assumed to be stable up to the formation of a mechanism.

Following the development of suitable procedures, some tests will be desirable.

2. Behavior of Continuous Columns

Elastic and plastic behavior of continuous columns will be studies, with particular reference to the reduction of axial load-carrying capacity due to bending moment causing yielding at certain sections along the column. Theoretical solutions to this type of problem are very much involved. Even though a considerable amount of research has been done on related problems both in this country and in Great Britain, a satisfactory design solution is not yet available.

These studies will be correlated with the "column" program (205A) (Some tests may be necessary.)

3. Frame Instability

For a relatively tall building frame, its over-all stability has considerable influence on its load-carrying capacity. In general the stability of a framework deteriorates after the formation of each plastic hinge, and reaching a limit when the frame is transformed to a mechanism. The general solution to this type of problem is not available at the present time and is likely proven difficult. Preliminary investigations will start on single-story rectangular frames under vertical load alone, by solving differential equations taking the effective moment of inertia of yielded portion into account. If a theoretical solution can be obtained in this manner, some tests on miniature frames will be needed.

It is hoped that these studies will supplement those to be carried out by Dr. Robert L. Ketter at the University of Buffalo.
WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS

List of Reports

I. Progress Reports, Published or for Publication

*1. Luxion, W. and Johnston, B. G.
   PLASTIC BEHAVIOR OF WIDE FLANGE BEAMS
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   F. L. 203.3, Reprint No. 63.

*2. Beedle, L. S.; Ready, J. A.; and Johnston, B. G.
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   MOMENT
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   F. L. 205.2, Reprint No. 72

*3. Yang, C. H.; Beedle, L. S.; and Johnston B. G.
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*4. Topractaloglu, A. A.; Beedle, L. S.; and Johnston, B. G.
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   PART I - Test Results and Requirements for Connec-
   tions, Welding Journal, 30(7), p. 359-s
   PART II - Theoretical Analysis of Straight Knees
   Welding Journal, 30(8), p. 397-s
   PART III - Discussion of Test Results and Con-
   clusions, Welding Journal, 31(11),
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6. Ketter, R. L.; Beedle, L. S.; and Johnston, B. G.
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*7. Ruzek, J.; Knudsen, K. E.; Johnston, E. R.; and
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   September 1954

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9. Yang, C.H.; Knudsen, K.E.; Johnston, B.G.; and
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ASCE Proc. Paper 1212, April 1957  
F. L. 205E.7

21. Driscoll, G. C.; Beedle, L.S.  
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27. Kusuda, T; Thurlimann, B.
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30. Driscoll, G. C., and Beedle, L. S.
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32. White, Maxwell
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   F. L. #205E.8, 1956.

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   F. L. #220A.29, June 1957.

36. Galambos, T. V., Ketter, R. L.
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   F. L. #205A.19

37. Smith, Jerome E.
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38. Project Staff
   SUMMARY REPORT
   F. L. 205.58, December, 1957

39. Fisher, J. W.
   PLASTIC ANALYSIS OF HAUNCHED CONNECTIONS
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   F. L. 273.1, September 1958
## WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS

### DISSERTATIONS AND THERSES

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<td>Topractsoglou, A. A.</td>
<td>CONNECTIONS FOR WELDED RIGID PORTAL FRAMES</td>
<td>1950</td>
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<td>205B.3</td>
<td>Yang, C. H.</td>
<td>THE PLASTIC BEHAVIOR OF CONTINUOUS BEAMS</td>
<td>1951</td>
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<td>Chen, C. H.</td>
<td>ELASTIC LATERAL BUCKLING OF I-SECTION COLUMNS</td>
<td>1950</td>
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<td>205C.14</td>
<td>Beedle, L. S.</td>
<td>ELASTIC, PLASTIC, AND COLLAPSE CHARACTERISTICS OF STRUCTURAL WELDED CONNECTIONS</td>
<td>1952</td>
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<td>205E.6</td>
<td>Haaijer, G.</td>
<td>LOCAL BUCKLING OF WF SHAPES IN THE PLASTIC RANGE</td>
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<td>Ketter, R. L.</td>
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<td>205C.20</td>
<td>Smith, J. E.</td>
<td>BEHAVIOR OF WELDED HAUNCHED CORNER CONNECTIONS (M.S. Thesis)</td>
<td>1956</td>
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<td>White, M.</td>
<td>THE LATERAL-TORSIONAL BUCKLING OF YELLED STRUCTURAL STEEL MEMBERS</td>
<td>1956</td>
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<td>205C.22</td>
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<td>PLASTIC ANALYSIS OF HAUNCHED CONNECTIONS (M.S. Thesis)</td>
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<td>Driscoll, G. C., Jr.</td>
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