1964 SUMMARY OF PROJECT DESCRIPTIONS & PLANS

WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS
(PLASTIC DESIGN)

Fritz Engineering Laboratory Report No. 273.22
1964 SUMMARY
OF
PROJECT DESCRIPTIONS & PLANS
WELDED CONTINUOUS FRAMES AND
THEIR COMPONENTS (PLASTIC DESIGN)

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Need a 205 final report this year
1) Project status, completed, phase charts, Time schedule
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1. **PROJECT DESCRIPTIONS & OUTLINES**

**WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS**

**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.)
Project Objectives:

To develop methods for predicting the ultimate load-carrying capacity of continuous steel structures and to develop practical design procedures for utilizing the reserve plastic strength.

This phase of the project deals with the efforts directed at preparing reports and commentaries to assist the designer, preparing specifications to make use of research results, and to present lectures at regional conferences to disseminate and interpret the research results.

Phases of Project 205:

I Initial Studies (completed)
II Evaluation (completed)
III Commentary on Plastic Design (completed)
IV Design Manual and Specifications (completed)
V Design Procedure: (completed)
VI Analysis Procedure (completed)
VII Use of Models (completed)
VIII Use of I-Shapes (deferred)
IX Regional Conferences and Lectures (completed)
X Bibliography (completed)

Status of Work:

This project was concerned with general supervision of the work on plastic design of single story frames and the preparation of design procedures, specifications, and interpretive reports. Participation in regional and national conferences of technical societies, universities and sponsoring industries was included in this phase.

Work of this nature concerned with single story frames will be completed as of June 30, 1964.

Further work of this nature is appropriate in the field of multi-story frames. Work and funds for this purpose listed under 205 in the proposal dated July 31, 1964 should be included instead under phases 273-XI and 273-XII.
205H LATERAL BRACING REQUIREMENTS

Project Objectives:

To determine the required spacing, strength and stiffness of the lateral bracing in plastically designed beams.

Project Phases:

205H-I Bracing Spacing.

205H-II Bracing Requirements.
Objective:

To determine the optimum lateral bracing spacing of A36 rolled wide-flange beams by experiment.

Outline of Work:

1. Experiments of beams with elastic adjacent spans (completed 205H.12)
2. Experiments on beams with yielded adjacent spans (completed 205H.12)

Status of Work:

The experimental work was completed in 1963. The test results were used in theoretical studies in project 297-3. Current work is carried on in conjunction with project 297-4 on the bracing requirements of beams under moment gradient (lateral and local buckling requirements).
Objective:

To perform experiments on practically braced beams to study the effectiveness of such bracing to prevent lateral buckling failure.

Outline of Work:

1. Experiments on the effectiveness of various types of lateral bracing (completed, 205H.6)

2. Formulation of design rules (completed, 297.11)

Status of Work:

Work was completed in June 1964
273 Plastic Design of Multi-Story Frames

Project Objective:

To apply the principles of plastic design to the design of multi-story frames in order to achieve any economy possible from the application of such principles.

Project Phases:

273-I Development of Design Methods for Braced Frames
273-II Tests of Plastically Designed Braced Frames
273-III Tests of Beam-and-Column Subassemblies in Multi-Story Frames
273-IV Plastic Analysis of Unbraced Frames Subjected to Unsymmetrical Gravity Loads or Combined Loads
273-V Development of Design Methods for Unbraced Frames Subjected to Unsymmetrical Gravity Loads or Combined Loads
273-VI Tests of Plastically Designed Unbraced Frames Subjected to Unsymmetrical Gravity Loads or Combined Loads
273-VII Use of Welded Built-Up, Hybrid and High Strength Columns in Frames
273-VIII Composite Girders in Multi-Story Frames
273-IX Stiffening Effect of Cladding
273-X Bolted Frames
273-XI Load Factors and Loading Conditions in Plastic Design
273-XII Evaluation Analysis and Design
273-XIII 1965 Summer Conference on "Plastic Design of Multi-Story Frames"
Objective:

In designing multi-story building frames, it is often advantageous to use bracing, such as X-bracing or K-bracing, to help resist the horizontal loads. The use of bracing reduces considerably the shear force in the columns and, consequently, the bending moment to be carried by the beams and columns is also reduced. The bracing can also effectively prevent the frame from swaying in the lateral direction and thus reduces the deflection of the frame.

In the current practice of building design, such frames are usually designed by the elastic or conventional method in which the design criterion is always the attainment of limiting stresses. An alternate and more logical approach would be to design the structures on the basis of their plastic strength. This approach is permitted only in the design of one or two story frames by the present AISC Specification, due to the lack of information concerning the plastic behavior of columns and frames. However, recent investigations conducted at Lehigh University have furnished the needed information not only for columns but also for beam-and-column subassemblages.* A concurrent research project is investigating the plastic strength of braced multi-story frames (Proj. 273-II). The purpose of this study is to develop design procedures for such frames, utilizing the newly obtained information.

Outline of Work:


2. Development of a design procedure in which all beams are designed plastically and columns elastically (completed, 273.3).

3. Theoretical study of the plastic strength of columns in frames (completed, 273.8, 273.10).

4. Preparation of charts to be used in the analysis and design of columns based on restrained column theories (partially completed, 273.10).

5. Analytical studies of the strength of subassemblages with and without sidesway (completed, 273.11 and 278.4).


7. Preparation of reports explaining the methods and introducing them to practicing design engineers. Useful design charts will be included in the reports.

* See the statement of the project "TESTS OF BEAM-AND-COLUMN SUBASSEMBLAGES IN MULTI-STORY FRAMES" (273-III).
Status

This study was initiated in January, 1958. The current work consists of 1) writing of a report for Item 1, 2) preparation of additional charts for use in column design, and 3) development of design procedures (Item 6). All work outlined above is expected to be completed by June, 1966.
Objective:

The plastic design of multi-story frames requires the knowledge of the behavior of subassemblies. A subassembly consists of a beam-column and the other structural members framing into its ends. Tests have been conducted on isolated subassemblies with ideal end conditions. However, a multi-story frame is composed of many subassemblies which are interdependent. In order to check the validity of the method for the plastic design of braced frames (developed in Proj. 273-I), it is necessary to compare the theory with actual frame behavior.

Four tests on braced multi-story frames are proposed to provide experimental data on the ultimate strength of multi-story frames to compare with plastic design methods. The frame itself (sections, geometry and bracing) is the same for all four tests; only the loading condition varies. The four loading conditions are: full dead and live load, full dead and partial live, and the previous two conditions with horizontal load.

The performance of bracing in multi-story frames will also be studied, with regard to its effectiveness in resisting horizontal forces and its interaction with the frame.

Outline of Work:

1. Design and fabrication of test setup and specimens (273.14A).
2. Test of four braced multi-story frames under the four loading conditions outlined above.
3. Analysis of data.
4. Comparison of the results with theory.
5. Preparation of reports describing the test setup and results together with recommendations for design method.

Status:

This study was initiated in June, 1963. Item 1 has been completed, and the current work is on Item 2. The completion date of this work will be June 30, 1966.
Objective:

In the analysis and design of multi-story frames, it is often convenient to divide the entire frame into a number of smaller units, each consisting of a column and its neighboring beams. Such a unit is referred to as "beam-and-column subassemblages." In braced frames the deformations of the subassemblages generally do not involve sway, while in unbraced frames sidesway occurs when horizontal loads are applied to the structures. Two types of subassemblages should therefore be considered in multi-story frame design; namely, sway subassemblages and non-sway subassemblages. Analytical procedures for predicting the behavior and strength of both types of subassemblages are available (273.11) and are being used in developing methods of designing braced and unbraced frames.

A number of experiments have been conducted on subassemblages in which the columns were bent in symmetrical single curvature and the results have shown close agreement with the theoretical predictions (278.10). However, no experimental information is available to check the validity of the analytical procedures for subassemblages whose columns are bent in double curvature. Also, additional tests on sway subassemblages are needed in order to observe the behavior and strength of this type of subassemblages. Therefore, the objective of this study is to obtain experimental data on the behavior of the above-mentioned subassemblages.

Outline of Work:

1. Design of test setup.
2. Planning and conducting a series of tests involving non-sway subassemblages subjected to bending moments causing double curvature deformation and sway subassemblages.
3. Analysis of the test results and correlating them with theoretical predictions.
4. Preparation of reports presenting the results with recommendations for incorporation in design procedures.

Status:

One year from July 1, 1965 to June 30, 1966.
Objective:

The objective of this project is to construct a method for predicting the inelastic in-plane behavior of unbraced multi-story frames subjected to gravity or gravity plus wind loads. The effects of stiffness reduction due to yielding and of sway deflection on ultimate load capacity are of particular interest in this study. These effects are not considered in presently available frame analysis methods. The result is a gap in the ability to predict structural behavior which has hampered efforts to formulate and validate design procedures for unbraced multi-story frames. This study is intended to help fill this gap.

Outline of Work:

1. Consideration of stiffness reduction due to yielding by numerical calculation of slope-deflection coefficients for partially yielded beams using moment-curvature data and the moment diagram.

2. Extension of Item 1 to columns using the column deflection curve concept.

3. Extension of moment-curvature data into the strain-hardening range.

4. Formulation of exact inelastic load-deflection solutions for selected continuous beam systems using idealized moment-curvature relations (which facilitate exact analysis).

5. Construction of an incremental, iterative process, using slope-deflection equations with variable coefficients, for the inelastic analysis of selected continuous beam systems. Verification of results with Item 4.

6. Application of inelastic beam and column procedures to the analysis of selected simple frames with consideration of sway deflection effects on equilibrium conditions. Comparison of predicted behavior with available frame stability test results, or previous theoretical work.

7. Extension of frame analysis procedure to larger (at least 3-story by 2-bay) frames. Comparison of predicted behavior with projected multi-story frame test results.

8. Preparation of reports describing inelastic slope-deflection analysis procedures for beams, columns, and frames.
9. Report comparison of predicted and observed behavior for projected multi-story frame tests.


Status:

Starting date: September, 1963
Completed work: Item 1
Current work: Items 4 and 5
Completion date: June 30, 1966
Objective:

The conventional method of designing unbraced frames subjected to loads which may produce sway accepts the attainment of limiting stresses as a design criterion. Recent investigations have demonstrated that the use of the inherent plastic strength of the frames as a design criterion is a more logical approach. However, due to the limitations on the available information regarding the behavior of swayed columns and frames, the AISC Specification (1963) permits the use of this approach for frames up to two stories high only.

The strength of columns with sway has recently been studied by an analytical method (273.11) and will be investigated experimentally in another project (Proj. 273-III). Also, the behavior of complete frames subjected to gravity loads and combined loads is being investigated theoretically and experimentally under two separate projects (Proj. 273-IV and Proj. 273-VI). The results obtained from these studies will provide the needed information for extending the plastic method to taller building frames. The purpose of this study is therefore to develop design procedures for unbraced multi-story frames subjected to loads causing sidesway.

Outline of Work:

1. Development of methods for the analysis and design of continuous columns permitted to sway.
2. Formulation of design procedures for unbraced multi-story frames permitted to sway.
3. Preparation of tables, charts and other design aids.
4. Preparation of reports describing the procedures and introducing them to practicing design engineers.

Status:

Three years from July, 1964 to June, 1967.
273-VI TESTS OF PLASTICALLY DESIGNED UNBRACED FRAMES
SUBJECTED TO UNSYMMETRICAL GRAVITY LOADS OR COMBINED LOADS

Objective:

When an unbraced frame is subjected to unsymmetrical gravity load or gravity load in combination with horizontal load, the structure will generally be deformed into a swayed configuration. In such a frame, the resistance to horizontal load is provided by the beams and columns. These members are also called upon to resist the secondary moments caused by the sway deflections. The analysis and design of this type of frame are being investigated in two concurrent projects (Proj. 273-IV and Proj. 273-V). The purposes of this investigation are: 1) to develop testing techniques for multi-story frames with sidesway, 2) to obtain experimental data on the behavior and strength of unbraced frames, and 3) to verify experimentally the design procedures to be developed in Proj. 273-V.

Outline of Work:

1. Planning of test program. It is tentatively planned to conduct four full-scale unbraced frame tests in this investigation. The dimensions and member sizes of the test frames will be similar to those of the braced frames tested in Proj. 273-II.

2. Design of test setup. It is expected that the testing apparatus and techniques developed in Proj. 273-II will also be used in these tests.

3. Testing of frames.

4. Analysis of results and comparison with theoretical predictions.

5. Preparation of reports presenting the results and giving recommendations for incorporation in design.

Status:

This program was started in September, 1963. The design of the test setup for these frames was done in conjunction with Proj. 273-II. The current work includes Item 1 and 2. The first test is scheduled for February, 1965. The entire test program will be completed by June, 1967.

How can they be the same? Shouldn't they be proportioned "closed"? Could more members be designed as critical... then repair as they fail?
Objective:

In many multi-story frames it is not possible to use rolled shapes as column members because the heavy loads demand larger sections. The usual practice is to use high-strength steel rolled columns or to build up larger members from plates or rolled shapes by welding. The purpose of this project is to develop procedures for incorporating such columns into plastic methods of design.

Outline of Work:

1. Study of the economic and structural advantage of using other than A36 rolled columns in multi-story frames.

2. Study of the domains of loading and geometry where rolled high-strength steel, welded built-up and hybrid columns should be used in (1) braced multi-story frames and (2) unbraced multi-story frames.

3. Investigation of the possibility of increasing frame stability with high-strength steel or built-up columns.

4. Development of CDC-data and design aids for the types of columns and situations which were found to be important in the studies of items 1, 2, and 3 above.

5. Incorporation of the results into the design methods developed in projects 273-I, 273-V, and 276-II, and to report the results of this work.

Status:

Work is to start on items 1, 2, and 3 in October, 1964. Completion date: June 1967.
Objective:

To study how to consider the effect of the bending strength and stiffness of composite steel and concrete beams in the design of steel multi-story frames.

Outline of Work

1. Literature survey on effect of composite beams on rigid frame action, especially with respect to effects in the negative moment region.

2. Theoretical study of end rotation stiffness of symmetrical uniformly loaded composite beams, assuming no composite action in negative moment regions. Beams to be subjected first to gravity loads in a fixed-ended condition followed by application of anti-symmetrical end moments simulating wind moments.

3. Planning and testing of about three composite beam tests to verify or assist in making a theory for the effects in Item 2.

4. Preparation of a report describing theoretical studies and tests. If study is conclusive, design recommendations will be made. If further action appears to be needed, a proposal for a further project will be made.

Status:

One year from July 1, 1965 to June 30, 1966.
Objective:

In conjunction with the development of plastic methods of design in Projects 273-I, 273-V and 276-II, it is desirable to examine critical loading conditions in plastically designed frames and to reevaluate the basis for the currently used load factors.

Outline of Work:

1. Study of critical load-combinations and determination of the domains in which these became controlling.

2. Development of a basis for using uniform load-factors of 1.70 and 1.30 for vertical and combined vertical and horizontal loads, respectively, throughout plastic design.

3. Study of load factors with respect to the relative probability of load intensity and distribution (live load reduction in lower stories).

Status:

Preliminary investigations are underway. Completion date June, 1967.
Objective:

Upon completion of the work on design methods for the plastic design of multi-story frames it will be necessary to update the present AISC Specification to include provisions for such design procedures as were developed. It will also be necessary to provide aids in the form of charts, tables, or computer programs to permit rapid plastic design of multi-story frames.

Outline of Work:

1. Prepare recommendations for specification revision as soon as a sufficient amount of the research is completed.

2. Prepare recommendations for the computation of desirable design aids.

3. Discuss, defend, and disseminate the information from research and the recommendations for specification revisions.

Status:

Start July 1965; complete June 30, 1968. This project assumes the obligations of former project 205 Evaluation Analysis and Design with regard to Multi-Story Frames.
Objectives:

The main objectives of the conference are as follows:

1. Inform civil engineering professors and professional engineers of recent progress in plastic analysis and design of multi-story steel building frames.

2. Introduce new design methods.

3. Illustrate design methods and behavior of frames by full-scale demonstration tests.

4. Provide opportunity for exchange of ideas between U.S. college professors and research workers and invited foreign authorities.

Outline of Work:

1. Preparation of conference lecture outlines.

2. Preparation of conference lecture notes to be printed and issued to participants immediately prior to the conference.

3. Planning of demonstration tests and instrumentation.

4. Planning tours and displays.

5. Planning for accommodation, meals, transportation, lecture facilities, entertainment, etc.

6. Planning for participation of selected foreign experts in the field.

7. Presentation of conference including lectures and demonstrations.

8. Preparation of a report on the results of tests conducted in the conference.

Status:

Work on items 1) and 5) is presently underway. The conference will be held from August 23 to September 1, 1965. Items 1) to 6) inclusive will be completed by June, 1965. Item 8) will be started after the conference is ended, and should be completed before June, 1966.
Project Objective:

To develop methods for predicting the instability behavior of multi-story rigid frames acting as a whole and to determine what modifications are required to the simple plastic theory. To develop methods for proportioning structures to assure the needed stability.

Project Phases:

276-I Buckling Analysis of Unbraced Frames Subjected to Symmetrical Gravity Loads

276-II Development of Design Methods for Unbraced Frames Subjected to Symmetrical Gravity Loads

276-III Tests of Plastically Designed Unbraced Frames Subjected to Symmetrical Gravity Loads
Objective:

When symmetrical gravity loads are placed on an unbraced multi-story frame, overall buckling may take place at a load level lower than that computed by the simple plastic theory. This type of failure is often referred to as "Frame Instability" and should be guarded against in the design. For frames of practical dimensions, frame instability is likely to occur after the stress in some portion of the frame has exceeded the elastic limit. The problem is therefore the determination of the buckling strength of partially yielded frames.

The objective of this investigation is to study the inelastic buckling behavior of frames and to develop methods for computing the buckling loads.

Outline of Work:

1. Extensive literature survey of existing methods and solutions to frame instability problems (completed, 276.2).

2. Model tests of single story frames with members of rectangular cross section and built-up box section. (All tests are completed and a report is pending, 276.4).

3. Theoretical studies to obtain solutions for single story frames subjected to symmetrical gravity loads (complete, 276.3, 276.5, 276.6 and 276.7).

4. Model tests of single story frames fabricated from a small WF section (completed, 276.9). These tests were conducted to check the validity of the solutions obtained in 3.

5. Evaluation of the influence of base restraints on the buckling strength of single story frames. (completed, 276.1).

6. Theoretical studies of the buckling of partially yielded multi-story frames subjected to symmetrical gravity loads (Partially completed, 276.14).

7. Development of approximate methods of buckling analysis.*

8. Preparation of reports describing the methods.

* The approximate methods developed in this study will be used in formulating design methods in the Project "Development of Design Methods for Unbraced Frames Subjected to Symmetrical Gravity Loads" (Proj. 276-II).
Status:

This study was started in September, 1958 and was concerned with the stability of single story frames (Items 1 through 5). After the completion of the study on single story frames, considerable amount of work has been done on multi-story frames. Current work is concentrated on Items 6 and 7. The program, as outlined above, is expected to be completed by June, 1966.
Objective:

In designing unbraced multi-story frames to carry gravity loads, one of the important factors to be considered is "Frame Instability". This phenomenon of failure is characterized by a sudden shift from a symmetrical deformed configuration to an anti-symmetrical configuration. Particular attention should therefore be given to this type of failure in the design. A design approach taking into account the reduction in strength due to over-all instability has been developed for one- or two-story frames (Fritz Lab. Report No. 276.7). The purpose of the study is to extend the same approach to taller frames.

It is also hoped that a design procedure based directly on the buckling strength may be developed so that better utilization of the strength of columns may be achieved by this procedure.

Outline of Work:

1. Study of the various analytical and approximate methods of inelastic buckling analysis.

2. Formulation of design procedures which will include the effort of over-all buckling. *

3. Preparation of reports describing the procedures and giving design examples.

Status:

The project will begin in July, 1965 and will end in June, 1967.

* The validity of the design procedures will be checked by conducting model frame tests (Proj. 276-III).
Objective:

During the course of investigations to develop methods for buckling analysis of multi-story frames (Proj. 276-I) and to formulate design procedures to take into account the effect of frame instability (Proj. 276-II), it is planned to conduct a series of model frame tests to supplement the theoretical development. The purposes of these tests are: 1) to observe the buckling behavior of multi-story frames, 2) to study the reduction in strength due to overall buckling, and 3) to confirm experimentally the design procedure to be developed in Proj. 276-II.

Outline of Work:

1. Design of test setup for an exploratory test (completed, 276.14).
2. Modification of the test setup used in 1.
3. Planning and conducting the tests.
4. Analysis of the test results and correlating them with theoretical predictions.
5. Preparation of reports presenting the test results with recommendations for incorporation in design procedures.

Status:

This program was initiated in September, 1962. Current work is on Items 2 and 3. The expected date of completion will be June, 1967.
Project Objective:

To study the behavior of beam-columns restrained by members framing into their ends and to generate information useful for designing steel multi-story frames.

Project Phases:

278-I Literature survey and theoretical study of Column Deflection Curves

278-II Application of restrained column theory in beam-and-column subassemblages.

278-III Experimental study of restrained columns.
Objectives:

To study the treatment of beam-columns with end restraint in the literature and to expand this knowledge into a practical method for analysing beam-columns in multi-story frames.

Outline of Work:

1. Literature survey and evaluation of present knowledge (completed 1958, F. L. Report 278.1).

2. Theoretical studies of the properties of column deflection curves (completed 1964, F. L. Reports 278.2, 278.3 and 278.12).

3. Development of methods for representing column-deflection curve data and computation of such data (computer programs are working and in use since 1962).

Status of Work:

Completed, August 1964 except for final publication of 278.12.
Objective:

To develop computational procedures for applying the theory from 278-I to subassemblies consisting of beam-columns and restraining beams, so that this may serve as a basis for the design of braced multi-story frames.

Outline of Work:

1. Development and publication of nomographs (completed 1962, 278.4).
2. Preparation of example problems (completed, 1962, 278.4).

Scope:

Work has been completed in 1962.
Objective:

To provide experimental proof that restrained column theory can be applied to beam-and-column subassemblages.

Outline of Work:

1. Development of a test procedure and establishment of testing techniques (completed, 1963, 278.7).

2. Experiments on six non-sway and one sway beam-and-column subassemblage.

3. Report on the tests (completed, August 1964, 278.10).

Scope of Work:

Completion of publication of reports. Project will be terminated June 30, 1965.
297 PLASTIC DESIGN IN HIGH-STRENGTH STEEL

Project Objective:

To develop design procedures and recommend design rules for the plastic design of high-strength steel frames.

Project Phases:

297-I Literature Survey
297-II Experimental Study of High-Strength Steel Members
297-III Lateral Bracing Requirements
297-IV Local Buckling
297-V Shear
297-VI Rotation and Deflection Requirements
297-VII Frame Tests
297-VIII Design Recommendations
273.22

297-I LITERATURE SURVEY

Objective:

To search the literature for work which is pertinent to the development of plastic design procedures for steel framed structures.

Outline of Work:

1. Collection of literature on experiments and the evaluation of the results of these; special emphasis is to be placed on new work and on tests not discussed in the Plastic Design Commentary. (completed 1963, 297.3).

2. Assembly of information on types of steels available in the U. S. A. (completed 1963, 297.2).

Status:

This work was completed in 1963.
Objectives:

The experimental determination of material and cross-sectional properties of representative rolled A441 wide-flange members; to perform tests on beams and beam-columns to verify existing or newly developed theory.

Outline of Work:

1. Material properties from tensile tests on coupons (297.8).
2. Residual stress measurements (297.8).
3. Concentric stub-column tests (297.8).
4. Eccentric stub-column tests (297.4, 297.8).
5. Beams under uniform moment (297.8).
6. Beams under moment gradient (297.8).
7. Beam-columns (297.8, 278.14).

Status:

All items were completed August 1964. Final publication of reports to be completed by December 1965.
Objectives:

To develop methods for determining the required spacing, strength and stiffness of the lateral bracing in plastically designed beams under uniform moment, and to recommend rules for bracing design which account for differences in yield strength.

Outline of Work:

1. Theoretical work on the lateral buckling of simply supported beams prior to and at the start of strain-hardening (297.6, 297.9).

2. Theoretical evaluation of the end restraint and the "effective length" factors (297.6, 297.9).

3. Investigation of the interrelationship between lateral buckling, local buckling and rotation capacity. (297.6, 297.9).

4. Comparison between theory and experiment (297.6, 297.9).

5. Rules for optimum bracing spacing. (297.6, 297.9).

6. Strength and stiffness requirements for bracing. (297.6, 297.11).

Status:

All items were completed in August, 1964. Final publication of reports to be completed by December, 1965.
Objectives:

Study of the local buckling behavior of flanges and webs above, at, and below the start of strain-hardening; recommendation of width-thickness limitations for design; evaluation of the possible usefulness of the post-local buckling range.

Outline of Work:

1. Development of an analytic expression for the strain-hardening shear modulus (297.6, 297.10).

2. Local buckling initiation in flanges of beams under uniform moment (297.6, 297.10).

3. Local buckling initiation in flanges of beams under moment gradient. (297.6, 297.10).


5. Theoretical study of post-local buckling behavior. (curat?)

6. Recommendations for width-thickness limitations (including the difference in yield strength) in plastic design.

7. Rotation capacity, bracing spacing and local buckling for beams under moment gradient.

8. Rotation capacity, lateral and local buckling in connections.

Status:

Items 1, 2, and 3 were completed in August, 1964. Work during 1964-1965 and 1965-1966 will be on the remaining items, with all phases completed by June 30, 1966. Work in item 8 is of an exploratory nature to see if further research is necessary or if a satisfactory solution is possible without further testing.
Objective:

To study the effect of shear and to recommend design procedure.

Outline of Work:

1. Literature research and evaluation of available knowledge to determine if:
   a) enough is known for formulation of design rules for a shear check in high-strength steel beams, or
   b) further work is necessary

2. Design of test program

3. Performance of tests and theoretical study

4. Formulation and recommendation of design rules.

Status:

Items 1 and 2 are to be completed by June 30, 1965, items 3 and 4 to be worked on during 1965-1966 and completed by June 30, 1966. Items 2 and 3 are undertaken only if this is found necessary from the work in item 1.
Objective:

To study if the members are able to provide the necessary rotation for mechanism formation and to investigate the magnitude of deflections at the failure of high-strength steel beams and frames.

Outline of Work:

1. Comparison of rotation capacities to rotation requirements for high-strength steel continuous beams and beam-and-column subassemblies.

2. Deflections of high-strength steel frames.

Status:

Work started July 1, 1964 and is to be completed June 30, 1966.
297-VII. FRAME TESTS

Objective:

To provide verification of the theory developed in the previous phases of Project 297 by test on rigid frame structures.

Outline of Work:

1. Planning of tests

2. Test of single-story, single-bay welded rectangular A441 rigid frame under constant vertical and variable horizontal load.

3. Test of a restrained column.

Status:

Planning to be complete by June 30, 1965; the two tests are to be part of the August 1965 summer conference.
Objective:

To formulate plastic design rules for high strength steel frames and to recommend changes in Part 2 of the 1963 AISC Specification.

Outline of Work:

1. Development and reporting the recommendations.
2. Discussion of the recommended changes in the Specification with the sponsoring committee.

Status:

Work to be performed in 1966, completion estimated June 30, 1966.
2. **BUDGET DETAILS 1965-66**

2.1 **Budgets Proposed July 31, 1964**

**Project Budgets:**

<table>
<thead>
<tr>
<th>Project Budgets</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>205 Evaluation Analysis and Design</td>
<td>$ 8,700</td>
</tr>
<tr>
<td>273 Plastic Design of Multi-Story Frames</td>
<td>53,000</td>
</tr>
<tr>
<td>273.1 Summer Course on Multi-Story Frames</td>
<td>16,000</td>
</tr>
<tr>
<td>276 Frame Stability</td>
<td>20,000</td>
</tr>
<tr>
<td>297 Plastic Design in High-Strength Steels</td>
<td>33,000</td>
</tr>
<tr>
<td><strong>Total Budgets 7-1-65 to 6-30-66</strong></td>
<td>$130,700</td>
</tr>
<tr>
<td><strong>Supplemental Budget 5-1-65 to 6-30-65</strong></td>
<td>13,700</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td>$144,400</td>
</tr>
</tbody>
</table>

**Proposed Fund Requests:**

- American Iron and Steel Institute (5-1-65 to 6-30-65): $ 13,700
- American Iron and Steel Institute (7-1-65 to 6-30-66): 112,500
- Welding Research Council: 1,000
- U. S. Navy Bureau of Ships: 12,200
- U. S. Navy Bureau of Yards and Docks: 5,000

**Total:** $144,400

2.2 **Budget Breakdown by Nature of Cost**

**Supervision**

(Beenle, Driscoll, Galambos, Lu, Harrison) $ 24,700

**Research Personnel**

(Hansell, Yura, Yarimci, Adams, Parikh, Kerfoot, Daniels, McNamee) 39,600

**Wages**

(Shop, Secretarial, Student Help) 23,500

**Total Payroll** $ 87,800
2.2 (Continued)

Overhead (33-1/3%--Except Summer Course) $25,933

Expenses
(Specimens, Gages, Stationery, Travel, Tuition, Computer, Reprints, etc.) $16,967

Total Budgets 7-1-65 to 6-30-66 $130,700

Expenses for Multi-Story Frame Tests
May, June 1965

Supplemental Expenses 1964-65 9,100

Grand Total Requests $144,400

2.3 Budget Breakdown by Project Phases 1965-66

205 Evaluation, Analysis and Design

273 Plastic Design of Multi-Story Frames

<table>
<thead>
<tr>
<th>Project</th>
<th>Description</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>273-I</td>
<td>Design Methods - Braced Frames</td>
<td>$1,500</td>
</tr>
<tr>
<td>273-II</td>
<td>Tests - Braced Frames</td>
<td>$8,500</td>
</tr>
<tr>
<td>273-III</td>
<td>Tests - Subassemblages</td>
<td>$4,000</td>
</tr>
<tr>
<td>273-IV</td>
<td>Analysis - Unbraced Frames</td>
<td>$10,000</td>
</tr>
<tr>
<td>273-V</td>
<td>Design Methods - Unbraced Frames</td>
<td>$10,000</td>
</tr>
<tr>
<td>273-VI</td>
<td>Tests - Unbraced Frames</td>
<td>$12,500</td>
</tr>
<tr>
<td>273-VII</td>
<td>High-Strength Columns in Frames (Hybrid, Built-Up, etc.)</td>
<td>$1,000</td>
</tr>
<tr>
<td>273-VIII</td>
<td>Composite Girders in Frames</td>
<td>$4,000</td>
</tr>
<tr>
<td>273-IX</td>
<td>Stiffening Effect of Cladding</td>
<td>----</td>
</tr>
<tr>
<td>273-X</td>
<td>Bolted Frames</td>
<td>----</td>
</tr>
<tr>
<td>273-XI</td>
<td>Load Factors</td>
<td>$3,400**</td>
</tr>
<tr>
<td>273-XII</td>
<td>Specifications and Design Aids</td>
<td>$6,800**</td>
</tr>
</tbody>
</table>

Total 273 $61,700**

** $8,700 proposed on July 31, 1964 transferred to Phases 273-XI and 273-XII.
### 273.22 (Continued)

#### 273-XIII Summer Conference
- $16,000

#### 276 Frame Stability
- **276-I** Stability Analysis - Unbraced Frames: $3,000
- **276-II** Stability Design - Unbraced Frames: $10,000
- **276-III** Stability Tests - Unbraced Frames: $7,000
- Total 276: $20,000

#### 297 Plastic Design in High Strength Steels

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>297-I</td>
<td>Literature Survey</td>
<td>---</td>
</tr>
<tr>
<td>297-II</td>
<td>Experimental Study</td>
<td>---</td>
</tr>
<tr>
<td>297-III</td>
<td>Lateral Bracing Requirements</td>
<td>$2,000</td>
</tr>
<tr>
<td>297-IV</td>
<td>Local Buckling</td>
<td>$12,000</td>
</tr>
<tr>
<td>297-V</td>
<td>Shear</td>
<td>$2,500</td>
</tr>
<tr>
<td>297-VI</td>
<td>Rotation and Deflection Requirements</td>
<td>$2,500</td>
</tr>
<tr>
<td>297-VII</td>
<td>Frame Tests</td>
<td>$10,000</td>
</tr>
<tr>
<td>297-VIII</td>
<td>Design Recommendations</td>
<td>$4,000</td>
</tr>
</tbody>
</table>
- Total 297: $33,000
3. TIME SCHEDULE OF PROJECT PHASES

WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS

<table>
<thead>
<tr>
<th>Phase No.</th>
<th>Title</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>273</td>
<td>PLASTIC DESIGN OF MULTI-STORY FRAMES</td>
<td></td>
</tr>
<tr>
<td>273-I</td>
<td>Design Methods - Braced Frames</td>
<td>s *</td>
</tr>
<tr>
<td>273-II</td>
<td>Tests - Braced Frames</td>
<td>s *</td>
</tr>
<tr>
<td>273-III</td>
<td>Tests - Subassemblages</td>
<td>s</td>
</tr>
<tr>
<td>273-IV</td>
<td>Analysis - Unbraced Frames</td>
<td>s *</td>
</tr>
<tr>
<td>273-V</td>
<td>Design Methods - Unbraced Frames</td>
<td>s *</td>
</tr>
<tr>
<td>273-VI</td>
<td>Tests - Unbraced Frames</td>
<td>s *</td>
</tr>
<tr>
<td>273-VII</td>
<td>High-Strength Columns in Frames (Hybrid, Built-Up, etc.)</td>
<td>s *</td>
</tr>
<tr>
<td>273-VIII</td>
<td>Composite Girders in Frames</td>
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<td>Stiffening Effect of Cladding</td>
<td>s</td>
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<tr>
<td>273-X</td>
<td>Bolted Frames</td>
<td>s</td>
</tr>
<tr>
<td>273-XI</td>
<td>Load Factors</td>
<td>s</td>
</tr>
<tr>
<td>273-XII</td>
<td>Specifications and Design Aids</td>
<td>s</td>
</tr>
<tr>
<td>273-XIII</td>
<td>Summer Conference</td>
<td>s</td>
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<tr>
<td>276</td>
<td>FRAME STABILITY</td>
<td></td>
</tr>
<tr>
<td>276-I</td>
<td>Stability Analysis - Unbraced Frames</td>
<td>s *</td>
</tr>
<tr>
<td>276-II</td>
<td>Stability Design - Unbraced Frames</td>
<td>s *</td>
</tr>
<tr>
<td>276-III</td>
<td>Stability Tests - Unbraced Frames</td>
<td>s *</td>
</tr>
</tbody>
</table>

"Year" indicates Fiscal Year July 1 to June 30
s work started in this fiscal year
* work active
c work completed in this fiscal year

Too short
3. (Continued)

<table>
<thead>
<tr>
<th>Phase No.</th>
<th>Title</th>
<th>Year</th>
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</thead>
<tbody>
<tr>
<td>205H</td>
<td>LATERAL BRACING REQUIREMENTS</td>
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</tr>
<tr>
<td>205H-I</td>
<td>Bracing Spacing</td>
<td>s</td>
</tr>
<tr>
<td>205H-II</td>
<td>Bracing Requirements</td>
<td>s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>278</th>
<th>RESTRAINED COLUMNS</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>278-I</td>
<td>Literature Survey and Theoretical Study of Column Deflection Curves</td>
<td>s</td>
</tr>
<tr>
<td>278-II</td>
<td>Applications to Subassemblies</td>
<td>s</td>
</tr>
<tr>
<td>278-III</td>
<td>Experimental Study</td>
<td>s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>297</th>
<th>PLASTIC DESIGN IN HIGH-STRENGTH STEEL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>297-I</td>
<td>Literature Survey</td>
<td>sc</td>
</tr>
<tr>
<td>297-II</td>
<td>Experimental Study</td>
<td>s</td>
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<tr>
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