1948

Project 205: general proposal

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ULTIMATE STRENGTH OF WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS

Progress Report "A"
(Not for Publication)

General

The starting date for the current project (the time at which financing to the amount of $10,500 was completed) was July 1, 1948. Prior to that time, tests of simply-supported beams had been completed. Apparatus for testing columns had been designed, fabricated, and a pilot test conducted on a 4WF13 column, 16-feet long. All column tests material had been purchased.

The project proposal was approved at the November 18, 1947 meeting in Washington, D. C. by the Structural Steel Committee on a 5-year basis at $13,000 per year. The recent approval by the AISI of a $2,500 contribution completed the budget for the first year.

Progress of the work to date and plans for the future will be reported below under the headings:

(a) Columns
(b) Beams, Continuous Beams, Simulated Frames
(c) Connections
(d) Frames

By way of review, the following statement of purpose is excerpted from the proposal:

> "In order to develop satisfactory design methods in which the unique advantages of welding can be realized this investigation of initial yielding and ultimate strength of welded continuous frames is proposed.
>
> "The ultimate objectives are two-fold:
>
> (1) to determine the basic behavior of beams, columns, welded joints, and welded frames, emphasizing plastic action; and

(2) to develop design procedures for continuous welded frames applicable to building and bridge construction"

COLUMNS

(C.H. Chen, Research Assistant)(1)

1. Two columns have been tested.

   (a) 8WF31, 7-feet in length — Simulate column in a rigid frame to be tested in the future.

   (b) 8WF40, 7-feet in length — Same as above

2. The third test specimen is in preparation. It is the first of the general series of which six or seven will be tested during the remainder of the first year.

3. See Appendix "A" also.

BEAMS, CONTINUOUS BEAMS & SIMULATED FRAMES

(C.H. Yang, Research Assistant)

1. Tests specimens were obtained.

2. Apparatus for conducting tests on continuous beams and simulated frames has been designed and completed. A general arrangement plan is attached as enclosure 1.

3. The first continuous beam test, in which a "fixed-ended" beam will be simulated, is ready and will be tested during the week of November 29.

4. The first control test (simply-supported beam, 8WF40) has been completed and curves plotted. Results were in substantial agreement with those of the previous simply-supported beam tests.

5. Progress Report No. 1, "Plastic Behavior of Wide Flange Beams", by W. W. Luxion & B. G. Johnston, was presented at the October meeting of the American Welding Society, and published in the November Welding Journal.

6. Coupon tests have been completed for 8WF40 sections.

7. 4-100 kip capacity dynamometers have been completed and calibrated.

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(1) All research assistants are on a half-time basis.

CONNECTIONS

(Jan Ruzek, Research Assistant)

1. Material for numerous tests is available, or has been procured.

2. Appendix "B" is presented with this report, summarizing plans for tests resulting from the survey of the literature.

FRAMES

(Jan Ruzek, Research Assistant)

1. Material for several tests is available.

2. The general arrangement for testing single-span frames has been completed (see enclosure 2). Detail drawings for test apparatus are partially completed. Fabrication has commenced.

Respectfully submitted,

Lynn S. Beedle
Research Engineer

Bruce G. Johnston
Director

LSB:BGJ:fs

CC: Mr. LaMotte Grover
Members of the Lehigh Subcommittee, Structural Steel Committee, WRC
U.S. Navy, Office of Naval Research, Attn: Dr. J. M. Robertson
Mr. S. Epstein, Chairman of AISI Review Subcommittee
Professor N. M. Newmark, Chairman, Subcommittee D, Committee on Research, CRC.
Mr. Paul H. Kratz

Appendix A

Column Investigations

(Objectives, Program of Tests, Observations)

1. Objectives of the program are:

   (a) to determine strength of columns under combined axial load and end moment,

   (b) to determine carry-over and stiffness factors in the elastic and plastic region,

   (c) to determine the effect on column behavior of a splice,

   (d) to determine the effect of reversing the sense of the applied moment, and

   (e) to conduct "control tests" to simulate behavior of columns in specific frames to be tested in the future. (two of these tests were planned and have been completed.)

2. Variables being considered:

   (a) L/r. X-X axis: 8WF31, 27-41-52; 4WF13, 56-83-115.
   Y-Y axis: 8WF31, 47-72-95; 4WF13, 97-145-197.

   (b) End Condition.

   (c) P/P_{cr}, the ratio of applied load to buckling load.

   (d) Flexure axis.

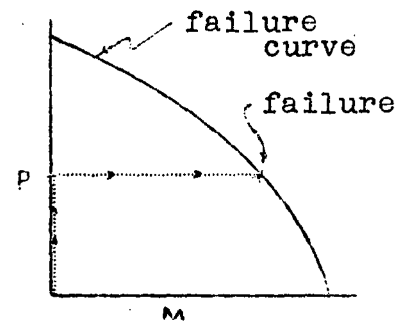
   (e) Size of specimen. (8WF31 and 4WF13)

3. Program of Tests: An adequate number of test specimens are available for several years work. A tentative program using all specimens available has been developed, but is not presented here.

The immediate program consists of six tests, three in each of the two sizes being studied. Test conditions "d" or "b" will be used. There will be wide variation in P/P_{cr}. The developed program will then be reviewed and modified as need be.

A literature study is underway with particular reference to the work directed by Prof. Baker in England. His group at Cambridge is now doing similar work, but small-scale models are being used.

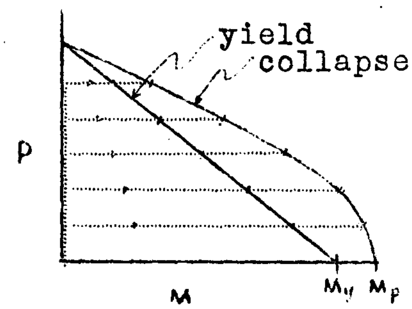
4. Method of Test: - The following procedure is employed on all tests: apply axial load, P, determined from the selected P/P_{cr}. Then, keeping P constant, increase the moment, M, to failure. See sketch "A". In a test simulating a column in a frame, P is determined from an analysis of the frame and is the value corresponding to the point of initial yielding.



A:- Method of Test

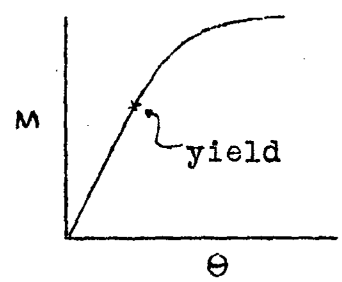
5. Observations and information to be obtained from tests:

(a) P-M relationship at initial yield and at collapse. See sketch "B". This is of principal importance.



B:- Interaction Curve

(b) Moment-angle change relationship. Curves obtained are of a type shown in sketch "C".



C:- Stiffness

(c) Ratio of end angle changes or of end moments at far and near ends... ...for use in evaluating carry-over factors.

(d) Deflection contours.

Appendix B

RIGID CONNECTIONS
TEST PROGRAM AND REVIEW OF LITERATURE

1. General - In the approved proposal submitted to the committee and to the Office of Naval Research it was stated that a study of literature would be made and actual tests (if required) would be based on this study. This appendix indicates the test program for corner connections only, with indication of future tests on other connection classifications (continuous column, etc).

2. Proposed Program of Tests - It is proposed to test connections as shown in Table I. Connection types that have come to our attention in the course of the literature study are shown in Fig. 1.

3. Notes on Program

    (a) References - Abstracts of those studied are at the end of this appendix.

    (b) Desirable characteristics of connections for use in fully continuous frames include:

        1) Rigidity - as near complete as possible to keep deflections to a minimum

        2) Strength - Sufficient to develop the full plastic moment in connecting members.

        3) Economy of fabrication and design simplicity.

    (c) Connection Types 4 & 7 - It is seen from the references that 7 is not as rigid as 4. According to some references both should have sufficient strength. According to reference 1, however, No. 7 is the weakest type and does not develop the hinge value.

    (d) Comparison between an isolated connection test and a full frame test on rather large scale has been made(10)* and correlation obtained. Thus a complete series of duplicating connection vs. frame tests probably is not necessary, although one or two comparisons might be desirable. A single connection type will be used in frame tests where some other variable is being studied.

    (e) Built-Up Members - Connections and frames should be tested. Detailed discussion deferred.

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*(10) Numbers indicate references. See list at end of this appendix.

(f) Type 5 included because references do not show relation with Type 4. Type 2 appears good if both members are of the same section. One of the continuous beam tests has the equivalent of such a connection. Types 7 and 4 are included because they are used. Thus a test of type 7 is important since the British tests[1] show it to be weaker than most of the others tested. Type 1 should be tested, too, since this was strongest in British tests. Note that Type 7 connection is being tested in a frame with both sections identical.

(g) Number of Tests - Test one of each type. If correlation with other tests is obtained, duplicate tests do not seem necessary.

(h) Detailed Design of Frames and Connections - The detailed design of connections 4 and 7 has been submitted to Lehigh by the Office of Naval Research. Approval for the use of this type is requested from the committee.

Detailed design of types 1 and 5 will be forwarded to members of the Committee upon completion and prior to fabrication of the specimens.

(i) Program for Remainder of Year - As stated in original proposal, the first year's work on connections was to include study of literature and several tests. The literature study will be continued as necessary, test apparatus will be built, and several connections tested.

The bibliography is attached.

App. B

BIBLIOGRAPHY
(Notes and abstracts included)

Ref.
No.
1 Braithwaite & Company, "Tests of Welded Frames", May 1, 1946.

Summary of results shown in the following table:

Type of Joint	Load (tons) at first sign of failure		Maximum load supported (tons)	
	TENSION	COMPRESSION	TENSION	COMPRESSION
1	3.0	3.4	above 5.0	4.5
2	3.0	1.9	4.4	*above 4.7
2	3.0	2.8	4.7	4.8
3	2.5	2.1	5.0	*above 3.3
7	2.0	1.7	5.0	*above 3.0
9	2.4	2.5	3.9	3.5

* The extent of the angular deformation of the joint suggests that the maximum load can only be very slightly above the figures given.

6" x 4½" steel joists were used. Tests carried to destruction. One test each in tension and compression.

Rigidity - Angle changes of beam and column were measured. No results summarized.

2 Mikuriya, T., "Study of Rigidity of Joint", April, 1930.

3 Stang, A. H., Greenspan, M., and Osgood, W. R., "Strength of a Riveted Steel Rigid Frame Having a Curved Inner Flange", Part of Journal of Research of the National Bureau of Standards, Vol. 21, Dec. 1939, p. 853. (RP 1161)

Contains study of stress-distribution patterns. The knee failed by elastic instability.

4 N. B. S., "Stress Distribution in Steel Rigid Frame Knees", AISC Progress Reports Nos. 1-10, research at National Bureau of Standards.

These are progress reports submitted in advance of refs. 3, 7, & 8. There are included studies of the effect of shifting of load line.

App. B.

5 Wilson, W. M., "Tests to Determine the Feasiblity of Welding The Steel Frames of Buildings for Complete Continuity", Welding Journal, Jan. 1936, Vol. 15, p. 28.

Strength: report shows connection types which develop the complete flexural strength of adjoining members--to flange stresses of 46,000 psi.

Rigidity: curves of rotation of joints for variation in detail of connection are shown on p. 32. As expected the Tee brackets top & bottom give most rigidity, plate at top is next, angle connections provide least rigidity, but all except tee type were seriously lacking in rigidity.

Reversal of load: fatigue tests run on several connection types. Many were "acceptable".

Beam-girder: connections were also tested.

6 Campus, F., "New Tests with Models of Rigid Joints", Translated by AISC from:

L'Ossature Metalligue, Number 3, 1940, pp. 125-142
" " , " 4, " , pp. 181-189

7 Stang, A. H., Greenspan, M., "Strength of a Welded Steel Rigid Frame", Part of Journal of Research of the National Bureau of Standards, Vol. 23, July 1939, pp. 145. (RP 1224)

Stress-distributions shown around knee. Failure due to buckling.

8 Stang, A. H., Greenspan, Martin, & Osgood, W. R., "Strength of a Riveted Steel Rigid Frame Having Straight Flanges", Part of Journal of Research of the National Bureau of Standards, Vol. 21, Sept. 1938, pp. 269. (RP 1130)

This was the first of three reports (the other two are refs. 7 and 3.) Report contains stress-distributions and direction of maximum and minimum stress.

9 Grover, L., "Manual of Design for ARC Welded Steel Structures", Published by Air Reduction Company, 1946.

Typical rigid frame connections shown on pp. 79-85. Chapter 10 contains discussion of top-plate and seat-angle connection.

10 Lyse, I. & Black, W. E., "An Investigation of Steel Rigid Frames", ASCE Transactions, 1942, p. 127 (including discussion)

These tests of frames checked the Bureau of Standards Tests of knees (refs. 3 & 8).

Rigidity: on p. 140 is shown a chart which indicates curved knee to be less rigid than square knee. This is in disagreement with Bleich's calcualtions of ref. 12 which indicate curved knee to be 1.25 times as rigid as square knee. Note, however, that there is no stiffening of webs or flanges in case of the curved knee and this is essential for rigidity.

Design: recommendation for design of square and curved knee are included.

11 Hussey, H. D., "Rigid Frames for Bridges and Buildings", AISC, 1937

Includes many examples of use of riveted and welded frames.

12 Bleich, F., "Design of Rigid Frame Knees", AISC, July 1943.

This is a study by F. Bleich on the design of two built-up knees, type 10 (riveted and welded, curved knee) and type 6 (welded square knee)

13 Roop, W. P., "Tests of Rigid-Frame Models", David Taylor Model Basin Progress Report, July 1942.

This is a progress report. Does not discuss test results.

14 Gibson, G. J., "Progress Report on Welded Beam-Column Connections" (mimeographed).

Contains discussion of restraint, test set-ups for tests of beam connected to two short columns. No fully continuous connections included.

15 Young, C. R., and Jackson, K. B., "The Relative Rigidity of Welded and Riveted Connections", Reprinted from Canadian Journal of Research, 1934, pp. 62.

Several variations of connection type IV.1 were tested. Both riveted and welded Beam-girder connections also tested. Program was not aimed at developing full continuity.

16 Baker, J. F. and J. W. Roderick, "Investigation into the Behavior of Welded Rigid Frame Structures", First Interim Report on the Behavior of seven portal frames. Trans. of the Institute of Welding, Vol. 1, No. 4, October, 1938, p. 206.

Models of portals were tested using I-shaped members $1\frac{1}{2}$" in depth. Measurement of rotations at various points in the knee were made. Types 3, a modification of 7, and type 7 with extra web plates added were tested. Rigidity increased in the same sequence, with type 3 being very weak.

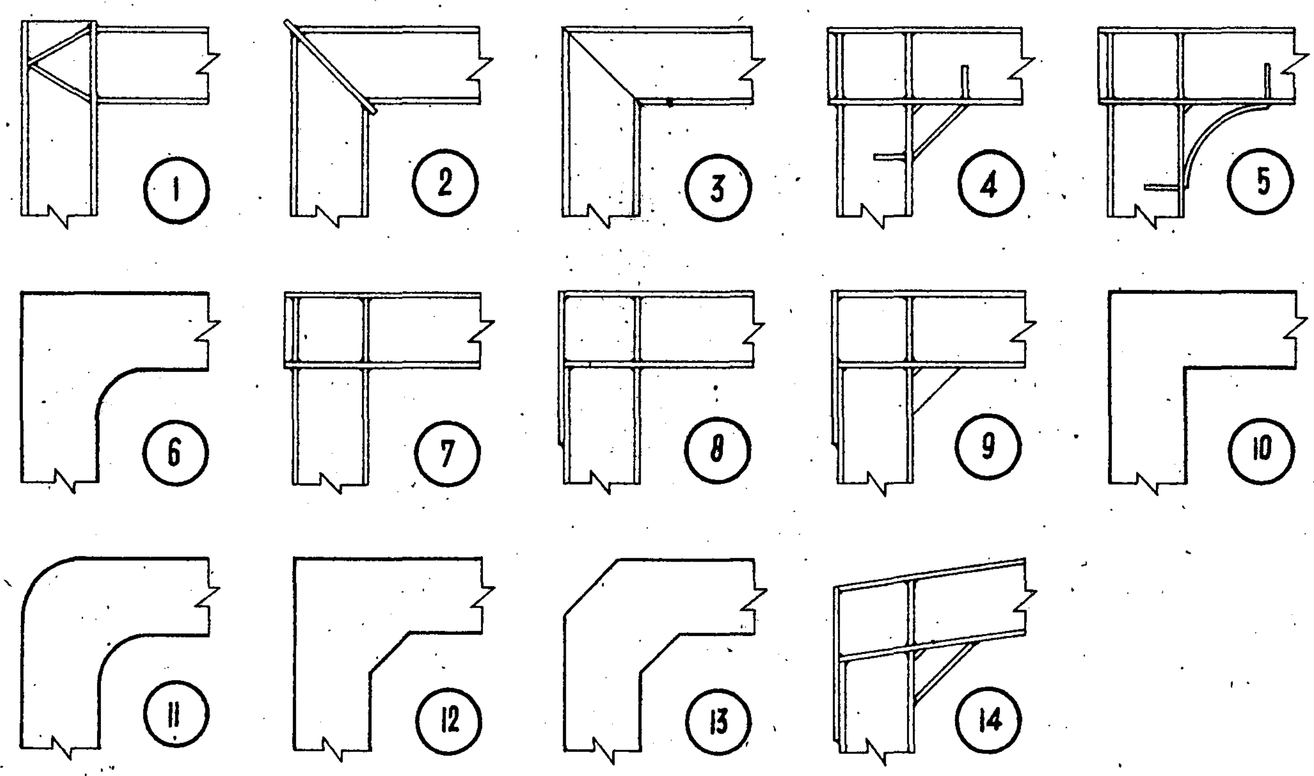
17 Van den Broek, "Theory of Limit Design", Wiley, 1948

Discusses general philosophy behind requirements of connections. p. 127.

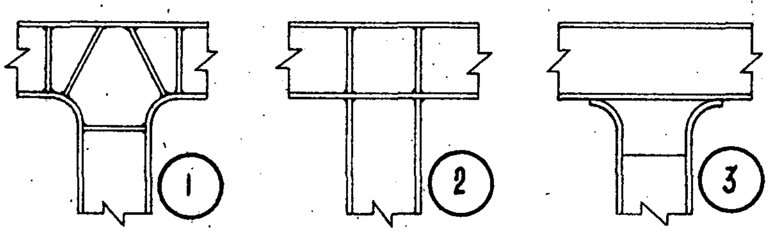
RIGID CONNECTIONS

App. B.

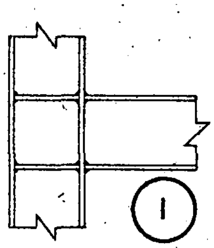
I. Corner connections.



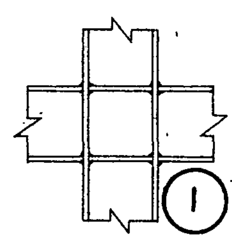
II. Interior column – Continuous beam.



III. Edge column – Column continuous.



IV. Interior column – Column continuous.



V. Column Y-axis type.

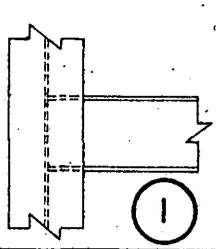
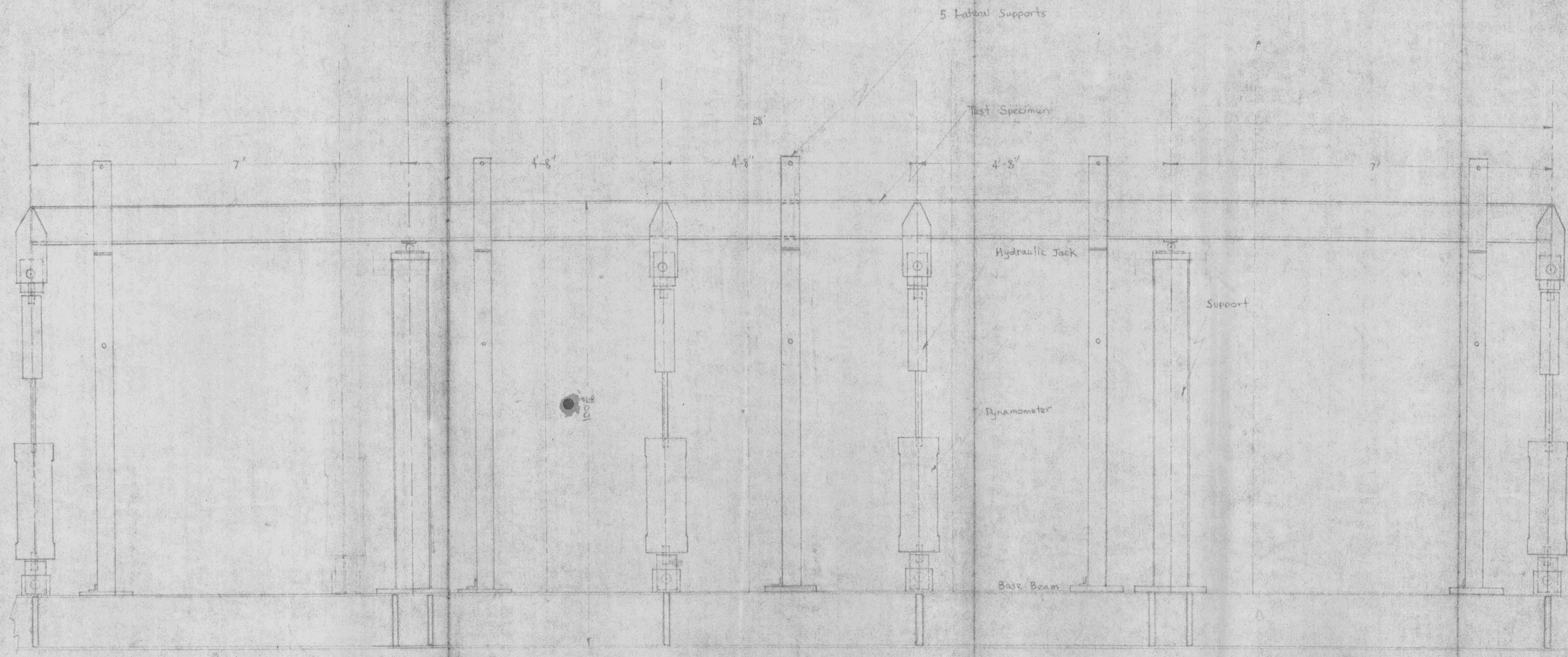
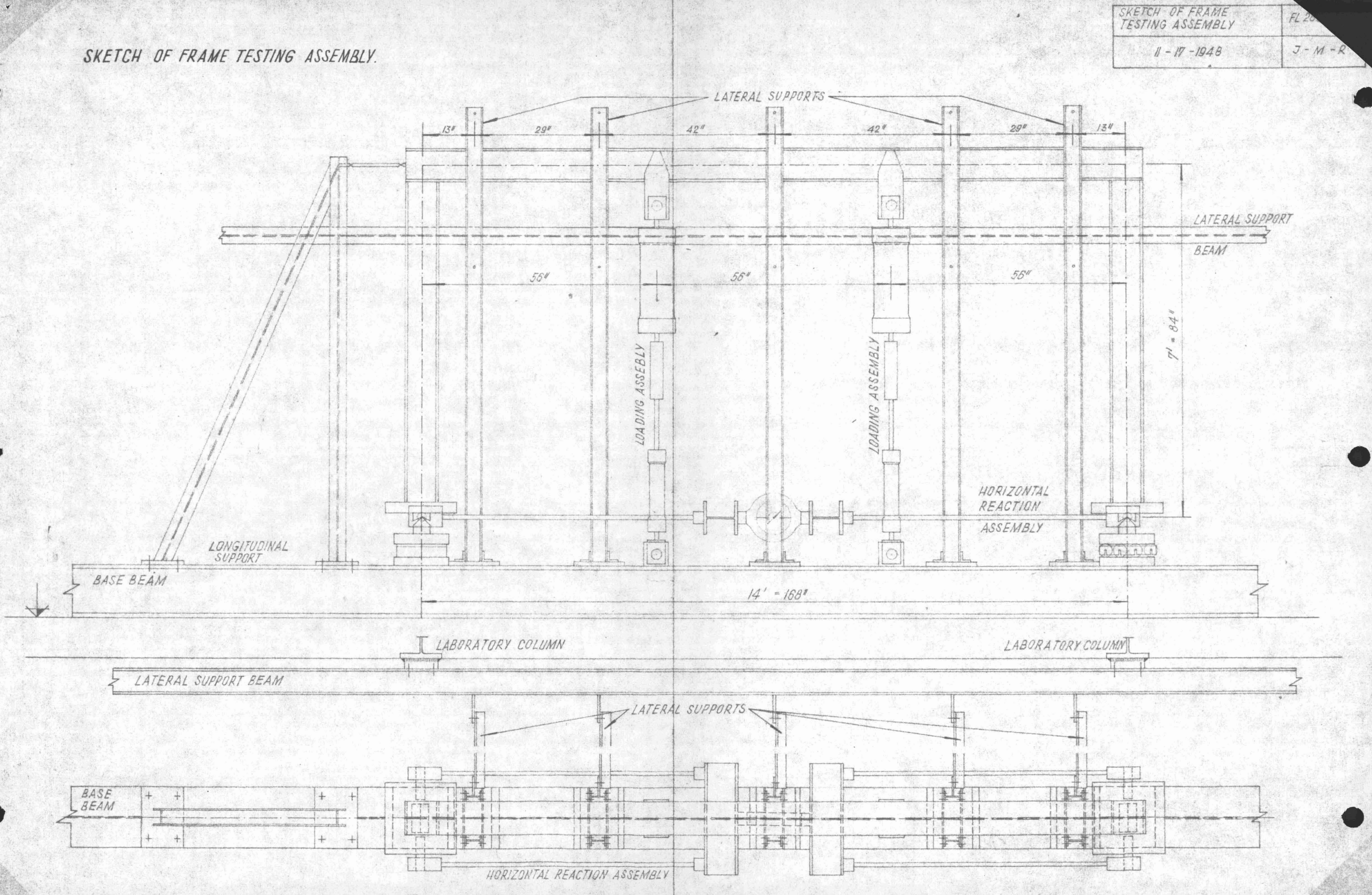


FIG. 1

GENERAL TEST SET UP	FL 205B-11
July 1, 48	H.Y.



CONTINOUS BEAM TEST SET UP


SKETCH OF FRAME TESTING ASSEMBLY
FL 20
11 - 17 - 1948
J - M - R
SKETCH OF FRAME TESTING ASSEMBLY.
LATERAL SUPPORTS
13"
29"
42"
42"
29"
13"
LATERAL SUPPORT
BEAM
56"
56"
56"
7' = 84"
LOADING ASSEBLY
LOADING ASSEMBLY
HORIZONTAL
REACTION
ASSEMBLY
LONGITUDINAL
SUPPORT
BASE BEAM
14' = 168"
LABORATORY COLUMN
LABORATORY COLUMN
LATERAL SUPPORT BEAM
LATERAL SUPPORTS
BASE
BEAM
HORIZONTAL REACTION ASSEMBLY

ENCL. 2