Proposal for braced multi-story frame tests, September 1963

J. A. Yura
L. W. Lu
G. C. Driscoll Jr.
Welded Continuous Frames and Their Components

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BRACED MULTI-STORY FRAME TESTS

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1. INTRODUCTION

In a steel structure subjected primarily to bending forces, simple plastic theory can generally be used to determine the ultimate strength. Extensive experimental work has been done on the components of such structures, that is, beams, columns, and connections. In addition, full-size frame tests have been used to study the interaction among the components and thus establish the plastic method of analysis experimentally.

Until recently the plastic method of analysis was restricted to structures composed of components primarily subjected to bending, such as one or two-story frames or the top stories of a multi-story frame. Members subjected to significant bending and axial force, beam-columns, introduce instability effects which retarded the use of ultimate strength methods.

However, recent theoretical investigations at Lehigh University have solved the beam-column problem in that the load-deformation characteristics can be predicted to ultimate load and even unloading. This solution has been incorporated in a method of analysis for the ultimate strength of a subassemblage. A subassemblage consists of a beam-column and the other structural members framing into its ends. The ultimate strength of a subassemblage is not necessarily the same as, and is usually greater than, the ultimate strength of the individual beam-column. It represents a more rational approach compared to the design of isolated members in a multi-story frame. Since the method can be applied to multi-story frames, it can be considered a major advance in ultimate strength design methods.
Tests nearing completion at Lehigh University have verified the method of analysis of subassemblages. In these tests isolated subassemblages with ideal end conditions were studied. However, a multi-story frame is composed of many subassemblages which are interdependent. In order to check the validity of the method for the ultimate strength design of multi-story frames, the theory must be checked with actual behavior. However, there are no full scale ultimate strength tests on frames in which axial force is significant.

It is the purpose of the proposed tests to provide experimental data of the ultimate strength of braced multi-story frames to compare with design methods. Important information on the interaction of subassemblages will be obtained in these multi-story frame tests which individual subassemblage tests cannot provide.
2. PROPOSED TEST PROGRAM

2.1 Test Arrangement

The proposed three-story, two-bay braced test frame is shown in Fig. 1. The columns are 15 ft. center-to-center and 30 ft. high. Standard welded construction will be used. This particular arrangement was chosen because it is composed of almost every type of subassemblage and it permits a checkerboard type loading condition. Two frames will be tested simultaneously in order to provide stability out of the plane of the frames. Suitable bracing will be provided to prevent out-of-plane behavior.

Loads are to be applied by means of hydraulic rams at the 1/3 points on each beam. The rams will be supported by towers located between the two frames. The tower design is shown in Fig. 2.

The column bases of the test frame will be fixed by means of prestressed anchorages, a detail of which is shown in Fig. 1. The bases are fixed in order to prevent failure at an early stage at an isolated point in the frame. If the bases were pinned, isolated failure of the interior column at the lower story would occur since a uniform column section is used.

Two tests are proposed. The frame will be the same for both tests, but the type of loading will vary.

2.2 Loading Conditions

The loading conditions for the two proposed tests are shown schematically in Fig. 3. The simulated uniform loads are shown only for clarity; actual loads will be concentrated at the 1/3 points.
The loading condition shown in Fig. 3a represents full dead and live loading on all the floors. The axial loads will be relatively high in the interior column but moments will be zero. There will be high axial forces and moments in the exterior columns. Approximate $P/P_y$ are shown for some of the columns. The exterior columns will be critical for this loading condition. Also, the loads on the top story are 0.80 of the loading on the lower two floors in order to prevent the formation of a beam mechanism in the top story.

The loading condition for the second frame test is shown in Fig. 3b. This checkerboard loading will produce critical single-curvature bending in the interior columns. This loading condition simulates full dead loading on all beams and full live load in alternate bays and floors. Some approximate $P/P_y$ in the columns are shown in the figure. Because the roof load is also reduced in this test, four separate loading systems will be required.

It should also be noted that the method of loading requires both the axial forces and the moments to be increased from zero to ultimate load. This is different from the individual subassemblage tests described previously in which an axial load was applied and kept constant during the test while the moment was increased from zero.

### 2.3 Description of Specimens

The proposed test frame consists of three different cross sections as shown in Fig. 1; the exterior columns are 6WF15.5 ($L/r = 47$), the interior columns are 6WF20 ($L/r = 45$), and the beams are 12 B 16.5. The columns are uniform from the base to the top story.
The column sections were chosen on the bases of realistic frame geometry and slenderness ratios commensurate with those in multi-story frames. Smaller column sizes would require a corresponding decrease in frame geometry which is not desirable. With the geometry shown, load contemplated would correspond to a 150 lb./sq. ft. working load if a load factor of 2 is used.

2.4 Instrumentation

It is proposed that one frame in both tests be instrumented extensively with strain gages to reduce the frame to a determinate structure. Instrumentation on the other (supporting) test frame of each test would be confined to critical areas for both auxiliary data and as a safety measure.

Rotations will be measured at all the joints in one frame with a few check measurements made on the supporting frame. The lateral deflection at each floor level will also be recorded.

An attempt will also be made to measure the forces in the principal bracing members.
The cost of these two tests was not included in the 1963-64 budget for the Multi-Story Frames project; therefore, additional funds will be required to carry out the proposed tests.

Each test, which consists of two frames, will cost approximately $1,200. This cost includes the test frames material, material for the determination of physical properties, bracing, fabrication and instrumentation.

In addition, twenty-four (24) twenty-ton rams must be purchased along with some auxiliary piping which will cost $2,000, and the towers which support the rams will also cost $2,000.

Consequently, the total cost for the proposed test program will be $6,400. Of this total, however, $4,000 is to be used to purchase and erect equipment which can be used for later tests. Tests of braced frames under combined horizontal and vertical loading and unbraced frames subjected to various vertical and horizontal loading conditions which may be proposed in the near future also would make extensive use of this equipment.
The two tests proposed will provide some insight into the ultimate strength of braced, multi-story frames. Since a test of this scale has not been done previously, it will also be an important contribution to structural knowledge in addition to providing experimental evidence for proposed ultimate-strength design methods for multi-story frames.

It should also be noted that almost all types of connections which are encountered in welded rigid-frame design are represented in the test frame. Consequently, connection behavior can also be observed.

It is expected that the experience and results from these tests will be of value in preparation for the 1965 summer course in plastic design of multi-story frames.
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6. FIGURES
Fig. 1
TEST FRAME

GWF 20

2][ - 15[33.9

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TEST FRAME

BRACING

Fig. 2
Fig. 3