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Instability analysis and test setup of three-story frames, September 1963

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INSTABILITY ANALYSIS AND TEST SETUP OF THREE-STORY FRAMES

by

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(For presentation at Committee Meeting only)

I. INTRODUCTION

One objective of the frame stability program is to determine the critical instability loads in multi-story frames under vertical loads.

The frames under vertical loads may sway sidewise suddenly when the loads reach the critical buckling loads. This phenomenon can occur at any stage, whether the frame is in the elastic range or inelastic range, depending on the stiffness of columns and beams.

As presented at the last subcommittee meeting in September 1962, an energy method, based on actual moment-curvature-thrust curves of a typical wide flange section, has been developed and is being tried on some examples.

II. RESULTS OF THEORETICAL ANALYSIS

Based on the theory developed, a series of computations have been made to determine the buckling loads of single-story, two-story and three-story frames with different slenderness ratios of columns.

The theory is primarily developed for frame analysis in the inelastic range. However, it has been tested in the pure elastic range as a particular case.

The solid curves in Fig. 1 and Fig. 2 indicate the effective length factor k vs. stiffness ratio γ relationships obtained from the energy method, when the specified structures buckle in antisymmetrical modes. The dotted curves corresponding to solutions which appeared in Tables 20, 21 and 22 of the book "BUCKLING STRENGTH OF METAL STRUCTURES" by F. Bleich. Close comparison between the results of the two methods can be observed for smaller stiffness ratios γ. For practical building frames, γ is about 1. For larger γ values, the frame should fail in the inelastic range. In this case both method are not valid.

This is one of reasons why an inelastic frame instability solution has been developed. Moreover the columns in multi-story frames are usually rather stout with varying slenderness ratios somewhere between 20 and 30, which should fail in the inelastic range according to the buckling analysis of a three-story frame in Fig. 3. The inelastic buckling curve gives a lower bound solution for frames with column slenderness ratios smaller than 60.

The three curves in Fig. 3 are the results of three computer programs based on three different methods. Curves were checked at several points by ordinary desk calculator. More discussion will appear in a subsequent report.

III. PROGRESS IN EXPERIMENTAL PROGRAM

There are two objectives for the test of three-story frames. First, the phenomenon of inelastic instability in multi-story building frames is to be explored with the relatively simple example of three-story frames. Second, the energy method developed may be checked by the test results. On the other hand the test results might lead to a further development of the theory.

Figure 4 shows dimensions and sizes of the frames to be tested. Model frames are designed accordingly and shown in the Drawings No. 4-1.

Two frames connected by a lateral bracing system will be tested at the same time. Similar to the previous single-story frame tests, loads will be applied by dead weights and lever systems. However, the design principles of the test setup are quite different from those of the single-story frame test.

The key to a sucessful test of bifurcation type instability in multi-story frames lies in perfect control over the misalignment of model frame and loading system as a whole in each story.

There are two causes leading to misalignment of the whole system i. e. misfits in the model frame and eccentricity of the loading system. The former cannot be eliminated while the latter can be adjusted. Therefore, the following features of the test setup are self-explanatory.

(1) Each floor has its own loading system.

(2) A system of H-shaped spreader beams on the floor beams is adjustable in both directions.

(3) A screw device is attached at one end of each magnification lever to adjust the lever ratio.

(4) The tie-down rod on the other end of the magnification lever is movable so that no horizontal reaction can be introduced in the system.

According to the above mentioned requirements, test setup was designed and shown in the Drawing No. 4-2.

After fabrication of the model frame, loading systems will be attached to the frame. At first the three magnification lever ratios will be adjusted by the readings from three dynamometers. Then misalignment can be adjusted from the top floor down. The strain gages at each side of the columns provide the whole picture of misalignment. Thus a perfect setup can be achieved by a set of initial loadings on the loading baskets. Subsequent load increments will be about a hundred pounds and then gradually reduced to ten pounds near the end of the test. At each load increment, strain gage readings and dynamometer readings will be taken. The deflection of the frame will be measured by transits and scales. Predidicted load-deflection curves will be compared with those from transits readings.

IV CONCLUDING REMARKS AND PROJECTED FUTURE WORK

Work to date has resulted in the formulation of an energy method for the solution of elastic and plastic frame stability problems and in the planning of some confirming tests.

The energy method was tried on some sample one-, two-, and three-story frames with loads applied directly on the columns and the calculated results were compared with results available in published literature. The predicted frame instability loads for one- and two-story frames by the elastic energy method gave values greater than the published solutions by about 4% or less within the range of practical stiffness ratio of column to beam.

The inelastic energy method showed that the reduction of load carrying capacity for three-story frames having a column with slenderness ratio 30, is more than 30% of the full yield load of the columns as shown in Fig. 3. Therefore a check against instability may be necessary in the lower story of rather high multi-story frames.

In the near future, the effect of beam stiffness and the effect of varying slenderness in the columns on instability of frames will be investigated by the same method.

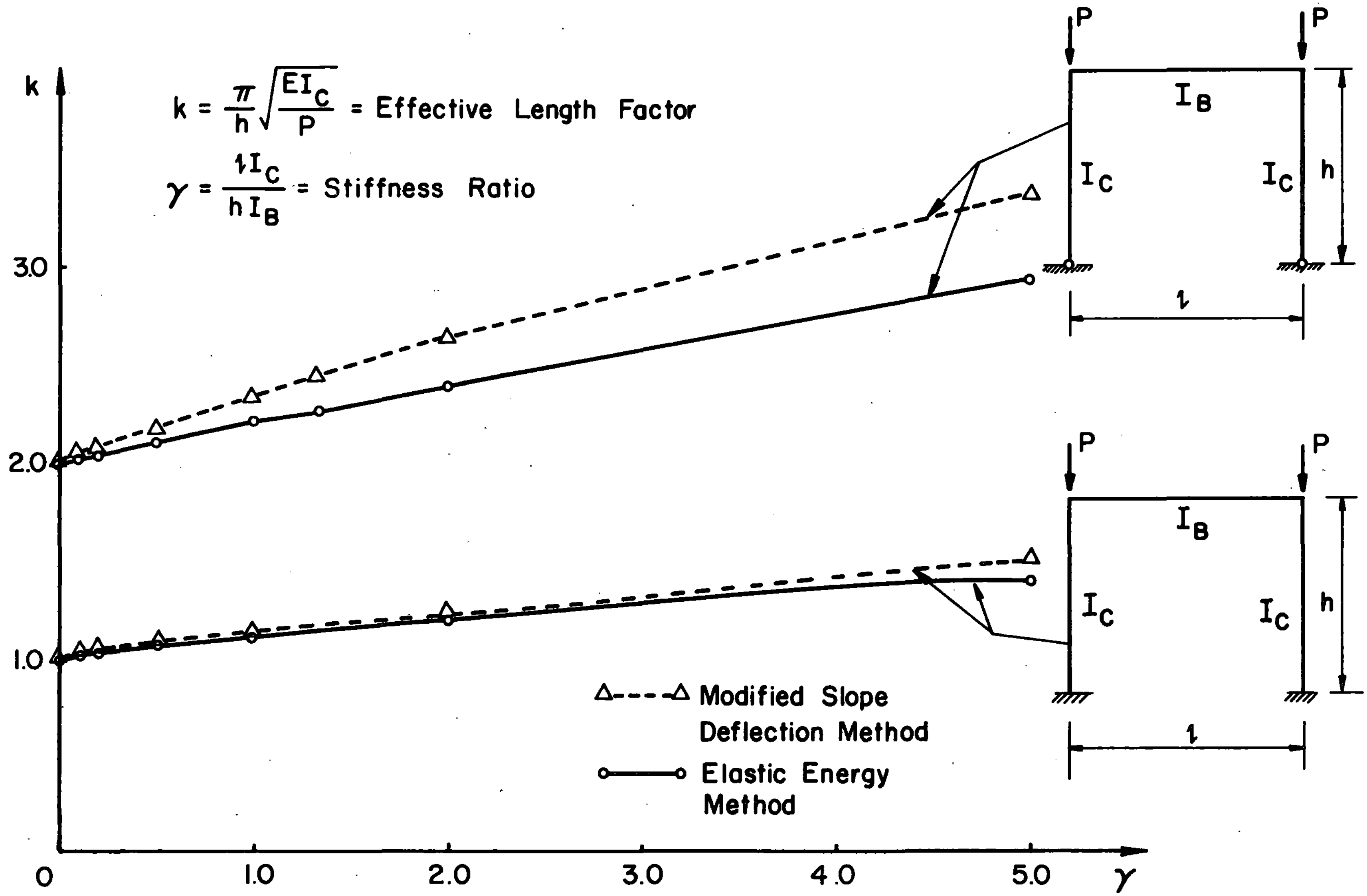


Fig. 1 ANTISYMMETRIC BUCKLING OF SINGLE-STORY FRAMES

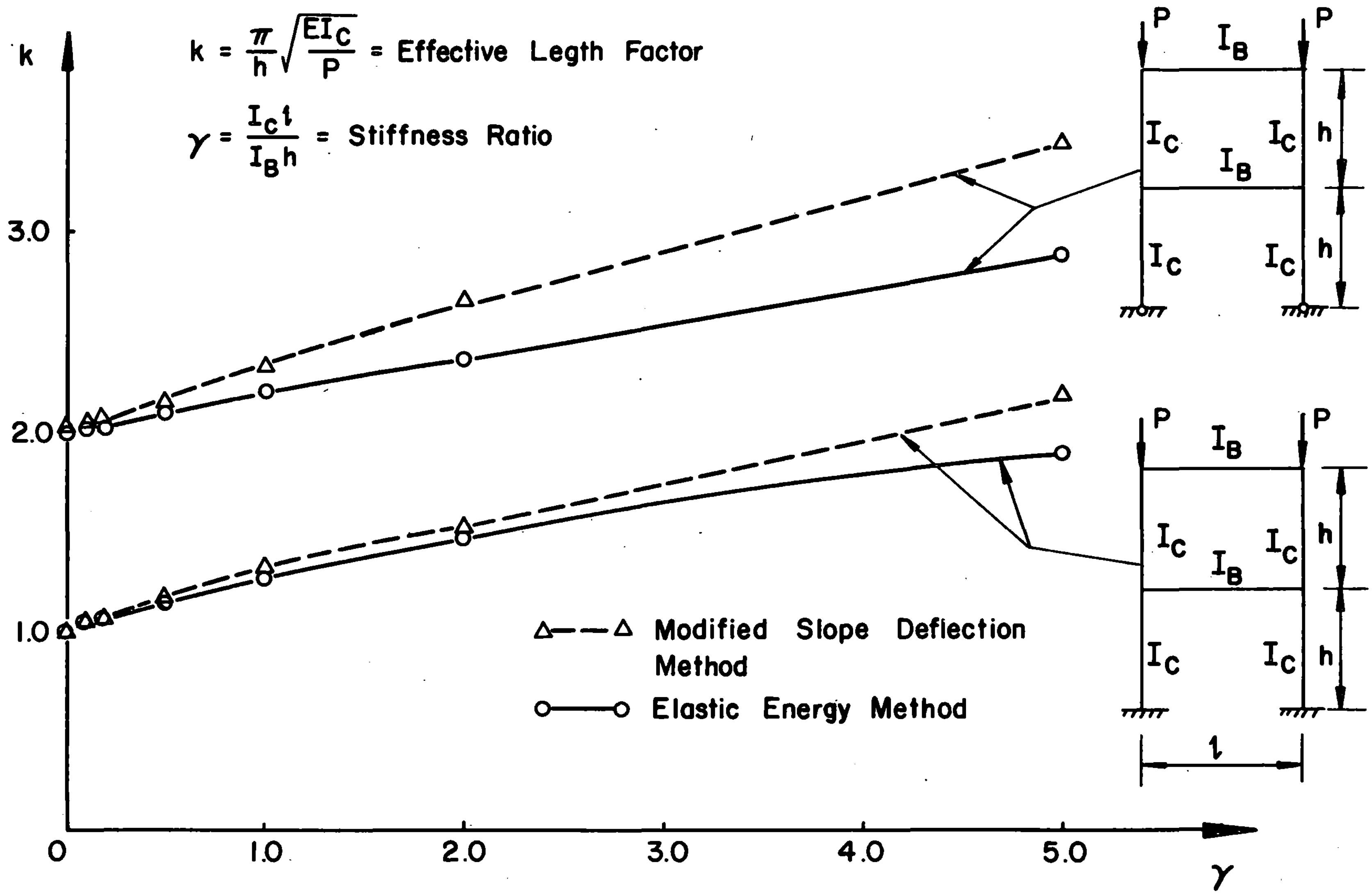


Fig. 2 ANTISYMMETRIC BUCKLING OF TWO-STORY FRAMES

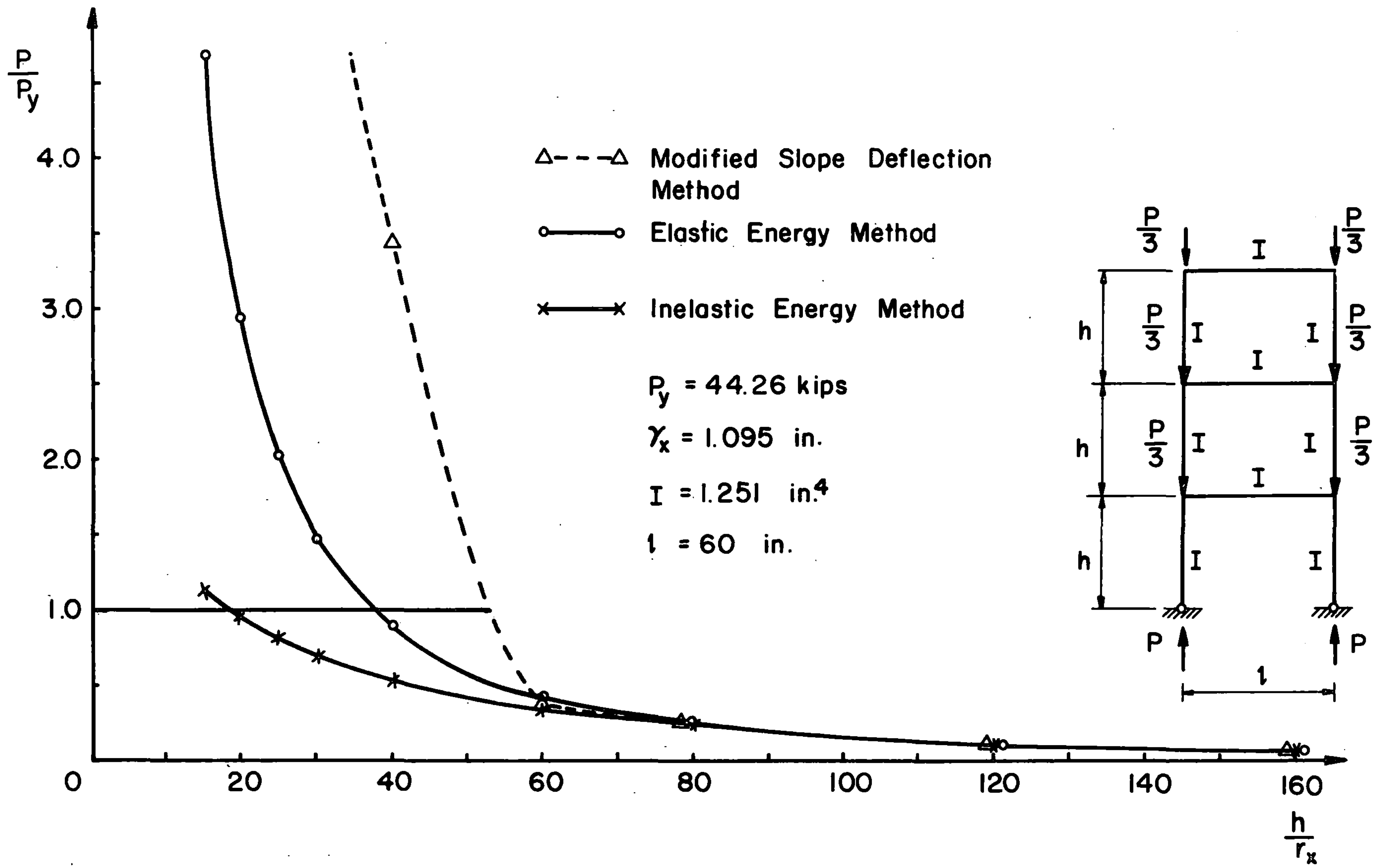


Fig. 3 ANTISYMMETRIC BUCKLING OF THREE-STORY FRAMES

Frame No.	Beam			Column				
	span L (in)	size	r_x(in)	$\frac{L}{r_x}$	Height h (in)	size	r_x(in)	$\frac{h}{r_x}$
U-1	60	$2\frac{5}{8}$ I3.7	1.095	54.8	33	$2\frac{5}{8}$ I3.7	1.095	30
U-2	60	$2\frac{5}{8}$ I3.7	1.095	54.8	44	$2\frac{5}{8}$ I3.7	1.095	40
U-3	60	3I5.7	1.230	48.8	33	$2\frac{5}{8}$ I3.7	1.095	30
U-4	60	3I5.7	1.230	48.8	44	$2\frac{5}{8}$ I3.7	1.095	40

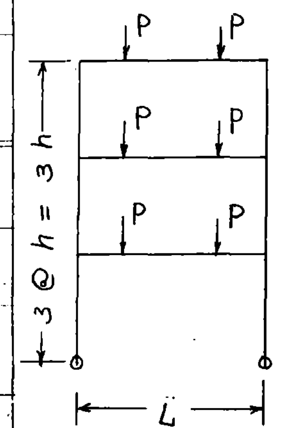
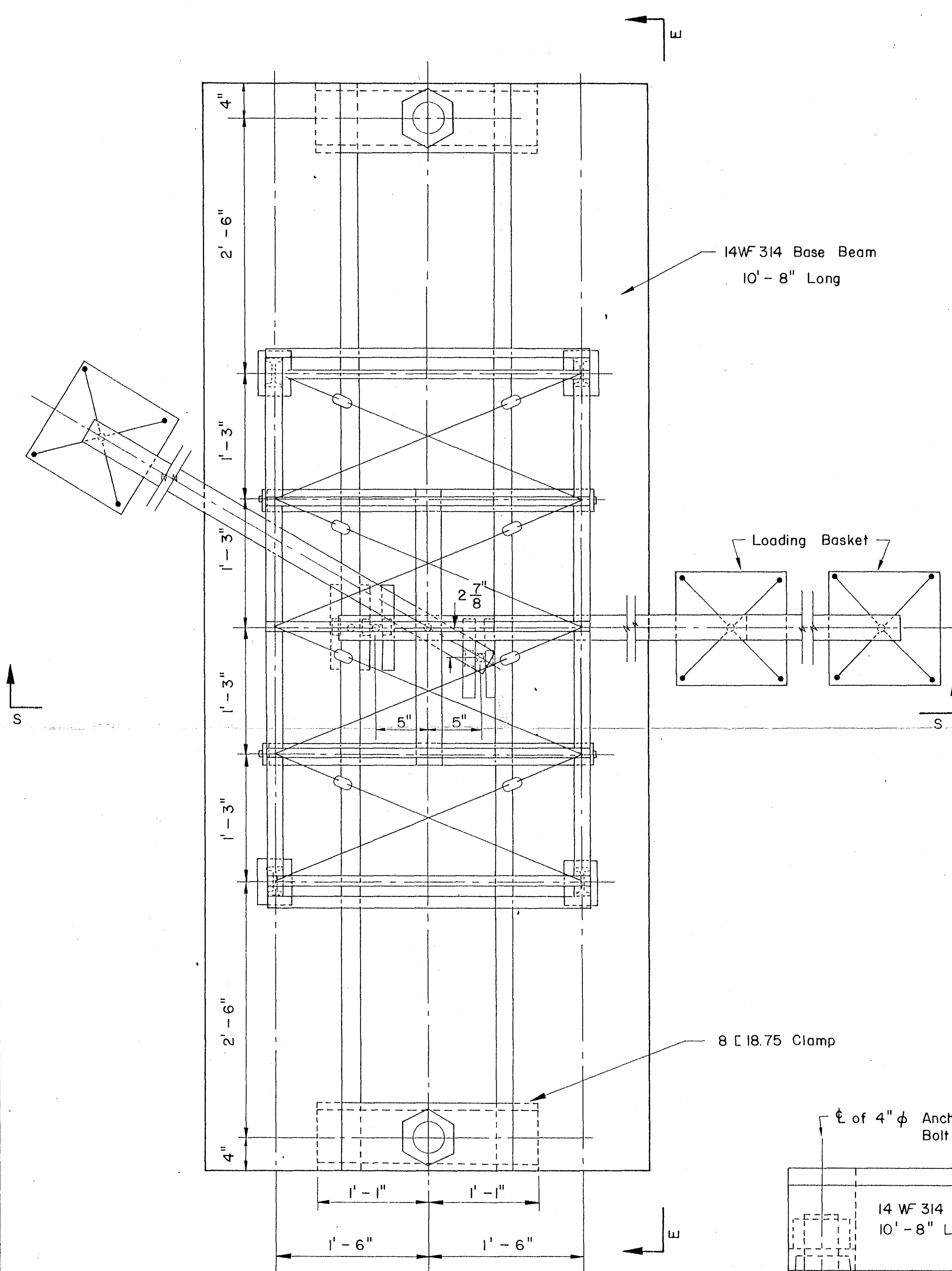
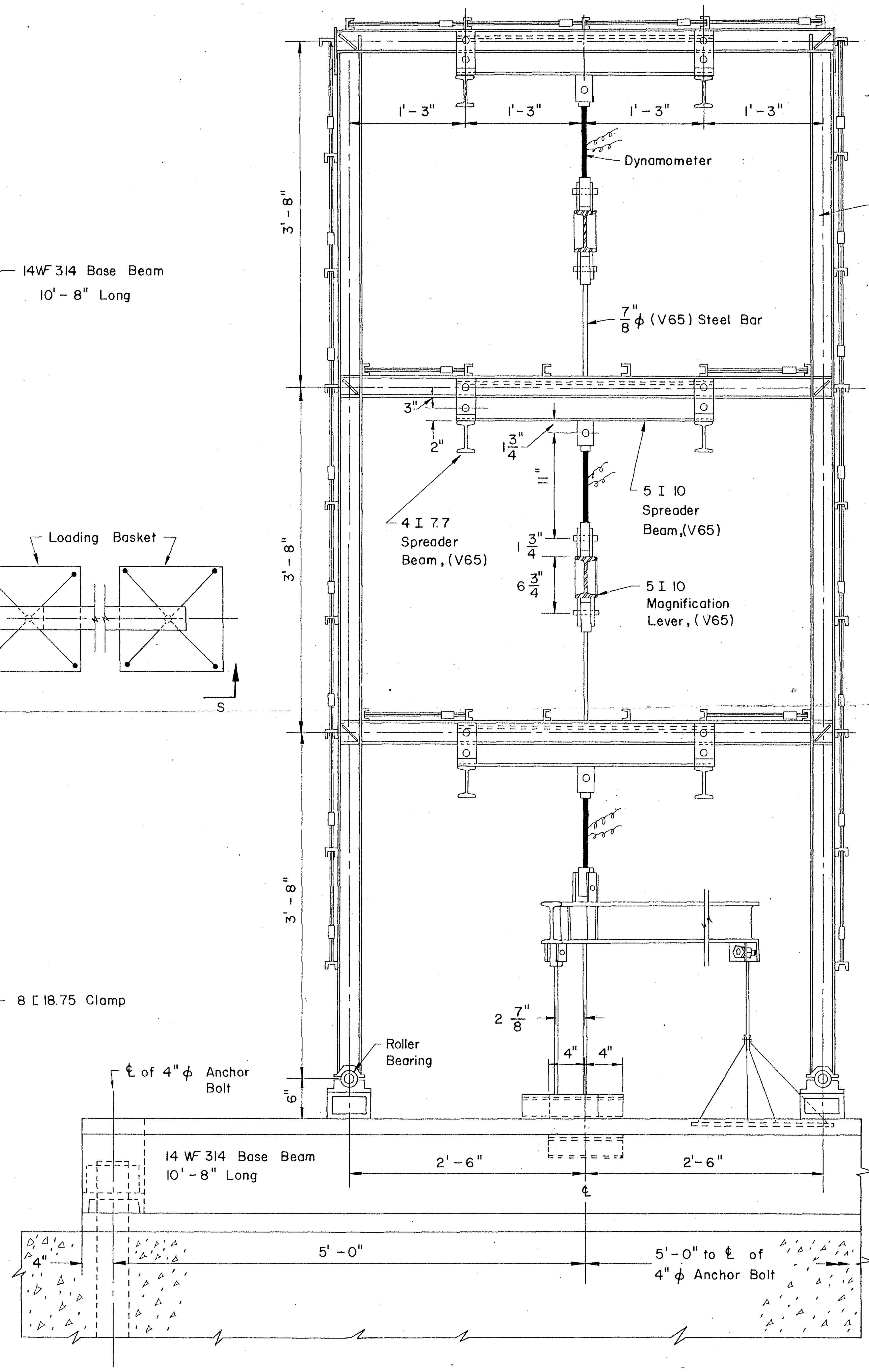


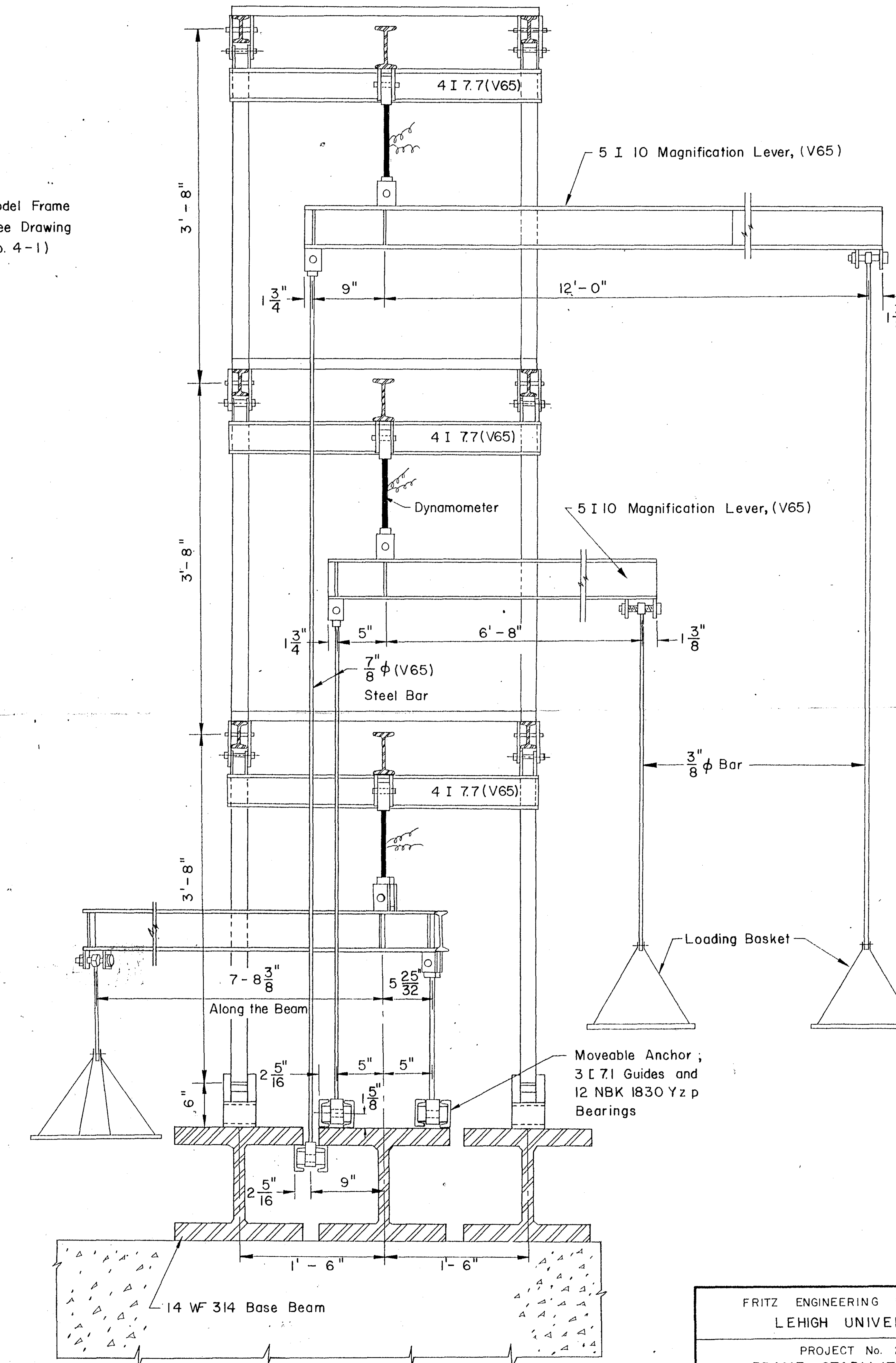
Fig. 4 PROPOSED TESTS OF UNBRACED FRAMES UNDER VERTICAL LOADS



PLAN



SECTION E – E



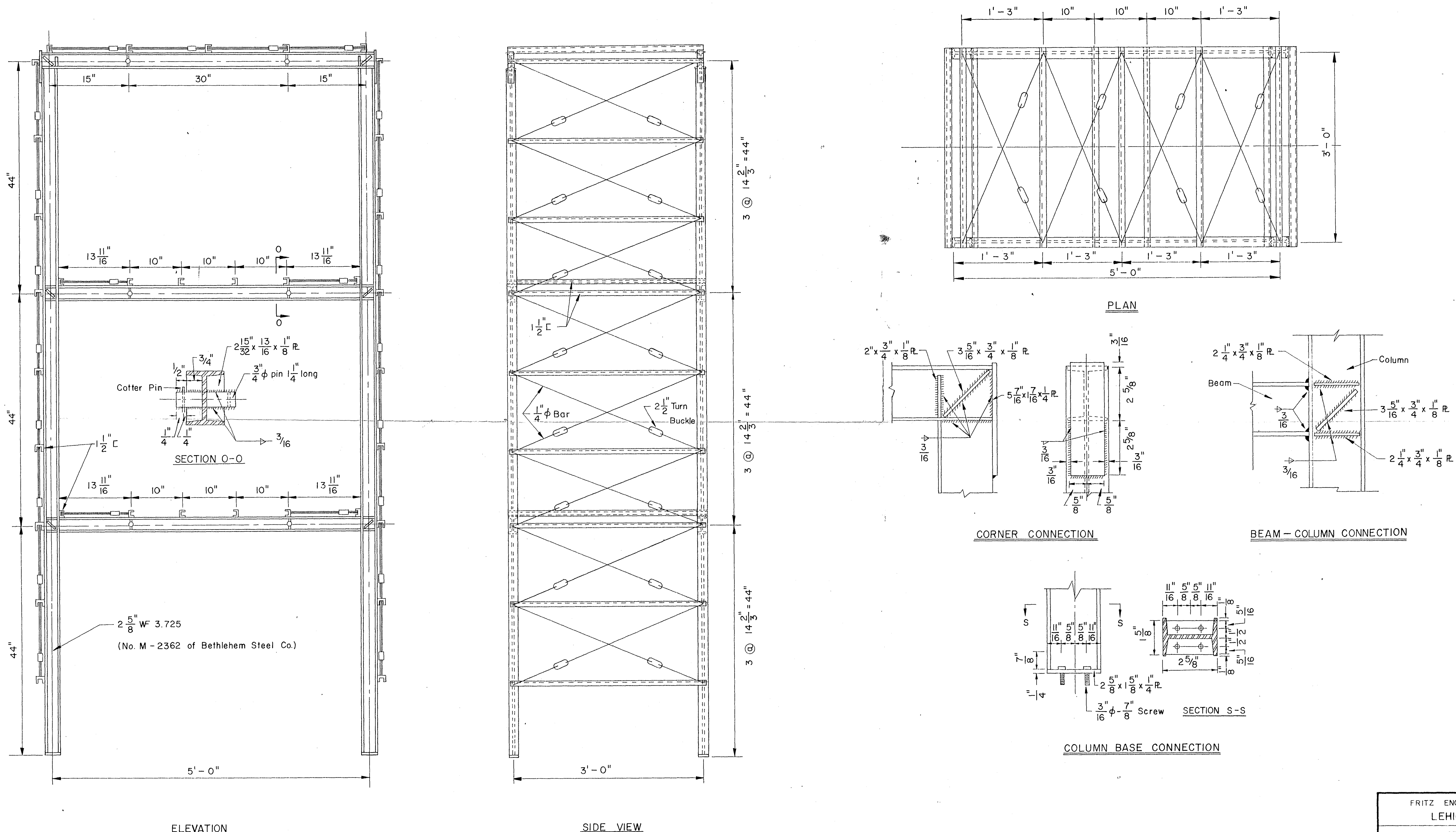
SECTION S-S

FRITZ ENGINEERING LABORATORY
LEHIGH UNIVERSITY

PROJECT No. 276
FRAME STABILITY TEST
TEST SETUP

Drawn by Y. C. Yen
Approved by

July 20, 1963 | No. 4-2



FRITZ ENGINEERING LABORATORY
LEHIGH UNIVERSITY

PROJECT No. 276
FRAME STABILITY TEST
MODEL FRAME

Drawn by J. C. Yen

Approved by

June 20, 1963 | No. 4-1