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205A.33
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PROJECT 205A

REPORT ON THE BEAM-COLUMN EXPERIMENTS

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1. Introduction

A list of the 22 column tests which were proposed in June 1958 is shown in Table 1. In July 1960, ten of these column experiments were completed. The date of testing, the test number, and the axial load ratio for the completed tests are shown in the last three columns of Table 1.

The primary purpose for the prepared tests was to determine the end rotation capacity of beam-columns by experiment. An extensive test program was planned because at the time the proposal was submitted no adequate theory for predicting the rotation capacity was available. Recent developments in connection with the project "Restrained Columns",* however, permit the theoretical determination of rotation capacity now. Good correlation was found to exist between theory and experiment (see Figs. 2 and 5), and therefore the objectives of the proposal of June 1958 have been reached. No further tests are planned in connection with this proposal.

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*See Ph.D. dissertation "Restrained Columns" by Morris Ojalvo (F.L. Report 278.3).

In the following a brief discussion is presented on the results of the experiments.

2. Description of the Experiments

All ten columns were tested in the five million pound testing machine. In each case axial load up to a predetermined magnitude was applied by the testing machine. Bending moment was then applied to the bottom of each column (loading condition "d" - see note at the bottom of Table 1) through a lever by a hydraulic jack until failure. The axial load was held constant throughout the experiment. For each experiment the bending moment was applied about the strong axis of the as-rolled wide-flange columns. The columns were braced against lateral-torsional buckling by a bracing system. Final failure was caused in each case by a combination of lateral and local buckling between the braces after the maximum load was reached. The following test information was obtained for each moment increment: the end rotations at the column ends, transverse deflections at four points along the column length, and the lateral deflections between the lateral braces. Auxiliary tests consisted of tensile coupon tests for each column. For several columns cross section tests were also performed to determine the magnitude of the maximum compressive residual stresses.

3. Significant Conclusions from the Tests

a. Column Strength

A comparison between the column strength theory of the report "Columns Under Combined Bending and Thrust" by R. L. Ketter and T. V. Galambos (F.L.Report 205A.21) and the experiments is shown in Table 2. This table also lists the member size, length, strong axis slenderness ratio, and the axial load ratio P/P_y for each test. There were three member sizes: 4WF13, 8WF31 and 8B13. The first two are typical column sections, and the last is a beam with a rather thin web (d/w=35). The axial load varied from very low ($0.12\ P_y$) to very high ($0.65\ P_y$), and the slenderness ratios were around 50, 80 and 110. The correlations between the maximum applied experimental bending moments and the corresponding theoretical predictions are quite good. The theoretical bending moments (column 7 in Table 2) were adjusted for the yield stress of the test material. The percentage difference between theory and experiment is generally not more than would be expected under normal experimental conditions.

Further comparison between the theoretical curves and the test results is shown in Fig. 1, where interaction curves from 205A.21 are shown as solid lines and tests are indicated by distinct points. The upper curve is for $L/r_x = 112$, and the lower curve is for $L/r_x = 55$ and 52.

The results of the comparison show that the theory is quite adequate for predicting column strength. The experiments have also indicated that the theory is valid for any type of wide-flange cross section.

b. Rotation Capacity

The primary purpose of the test program was to determine the rotation capacity of the column ends as the length, the axial force, the member size, and the loading condition were varied. Lateral bracing was provided in order to prevent premature unloading due to lateral-torsional buckling.

Three typical end moment-versus-end rotation curves are shown in Fig. 2. These curves are for tests A-2, 3 and 4; the slenderness ratio was 55 and the columns were 8WF31 sections. The axial load was as shown in the figure. Two curves are shown for each experiment: the straight lines connecting dots form the test curves, and the dashed lines are the theoretical curves. The latter were computed from the information contained in F.L. Report 278.3 (Morris Ojalvo, "Restrained Columns".), and they correspond to the L/r and the P/P_y of the experiments. For the three cases given in Fig. 2, it can be seen that the theory predicts the load-deformation behavior of the beam-columns quite well. Even better correlation was obtained for most of the other tests (not shown here), with the exception of Test A-1, where fixture binding caused restraints, and therefore the theory underestimated rotation capacity to a considerable extent, and tests A-8 and A-9, where unloading due to the local buckling of the web took place before it was expected by theory. In the latter two cases rotation capacity was limited by local buckling at relatively high strains.

From the comparison between the actual and the predicted M-θ curves for these ten experiments it can be concluded that the moment-rotation behavior can be adequately predicted from theory. Figure 3 illustrated how rotation capacity (which is defined on the top right corner of Fig. 3 as the rotation at $0.95\ (M_o)_{max}$ on the unloading part of the curve) varies with the slenderness-ratio and the axial force for loading condition "d". It is seen that rotation capacity increases as the axial force and the slenderness ratio decrease. Figure 5 shows the variation of rotation capacity with loading condition. Very little rotation capacity is seen to exist for loading case "c" (equal end moments causing single curvature deformation, $M_{TOP}/M_{BOTTOM} = 1$), whereas for double curvature deformation large rotation capacities can be expected.

A comparison between theoretical and experimental rotation capacities is shown in Fig. 5. This comparison shows good correlation. For reasons discussed above, no points are shown for tests A-1, 8 and 9.

TABLE 1

Proposed Test No.	Loading Condition	Section	P/P_y	L/r_x	Date Tested	Test No.	Test P/P_y
1	d	8WF31	0.3	54			
2	d	8WF31	0.3	54	Mar.1959	A-3	0.33
3	d	8WF31	0.4	54			
4	d	8WF31	0.5	54	Mar.1959	A-4	0.49
5	d	8WF31	0.6	54	Mar.1959	A-2	0.65
5a	a	8WF31	0.6	54			
6	d	8WF31	0.6	42			
7	d	8WF31	0.3	28			
8	d	4WF13	0.3	84	Aug.1958	A-1	0.33
9	d	4WF13	0.5	84			
10	d	4WF13	0.3	111	July,1959	A-5	0.33
11	d	4WF13	0.4	111	July,1959	A-7	0.16
11a	d	4WF13	0.6	111	July,1959	A-6	0.50
12	d	8B13	0.3	60	July,1960	A-8	0.30
13	d	8B13	0.4	60	July,1960	A-9	0.12
14	d	8B13	0.5	60			
15	d	8B13	0.6	60	July,1960	A-10	0.60
16	c	4WF13	0.3	84			
17	c	4WF13	0.3	56			
18	c	4WF13	0.3	56			
19	a	4WF13	0.3	84			
20	b	4WF13	0.3	84			

NOTE: Loading condition "d" : moment at one end only.

Loading condition "c" : two equal end moments causing single curvature deformation.

Loading condition "a" : two equal end moments causing double curvature deformation.

Loading condition "b" : moment applied at one end only while the other end remains fixed.

TABLE 2

Test No.	Size	Length	L/r_x	P/P_y	$(M_o/M_p)_{max}$ Experi-mental	$(M_o/M_p)_{max}$ Theore-tical	% Diff-erence
A-1	4WF13	12'-0"	84	0.326	0.725	0.661	+9%
A-2	8WF31	16'-0"	55	0.647	0.367	0.345	+6%
A-3	8WF31	16'-0"	55	0.326	0.815	0.751	+8%
A-4	8WF31	16'-0"	55	0.487	0.600	0.550	+8%
A-5	4WF13	16'-0"	111	0.332	0.466	0.484	-4%
A-6	4WF13	16'-0"	112	0.502	0.141	0.130	+8%
A-7	4WF13	16'-0"	112	0.158	0.884	0.872	+1%
A-8	8B13	14'-0"	52	0.300	0.779	0.773	-1%
A-9	8B13	14'-0"	52	0.120	0.964	0.960	0%
A-10	8B13	14'-0"	52	0.600	0.458	0.403	+14%

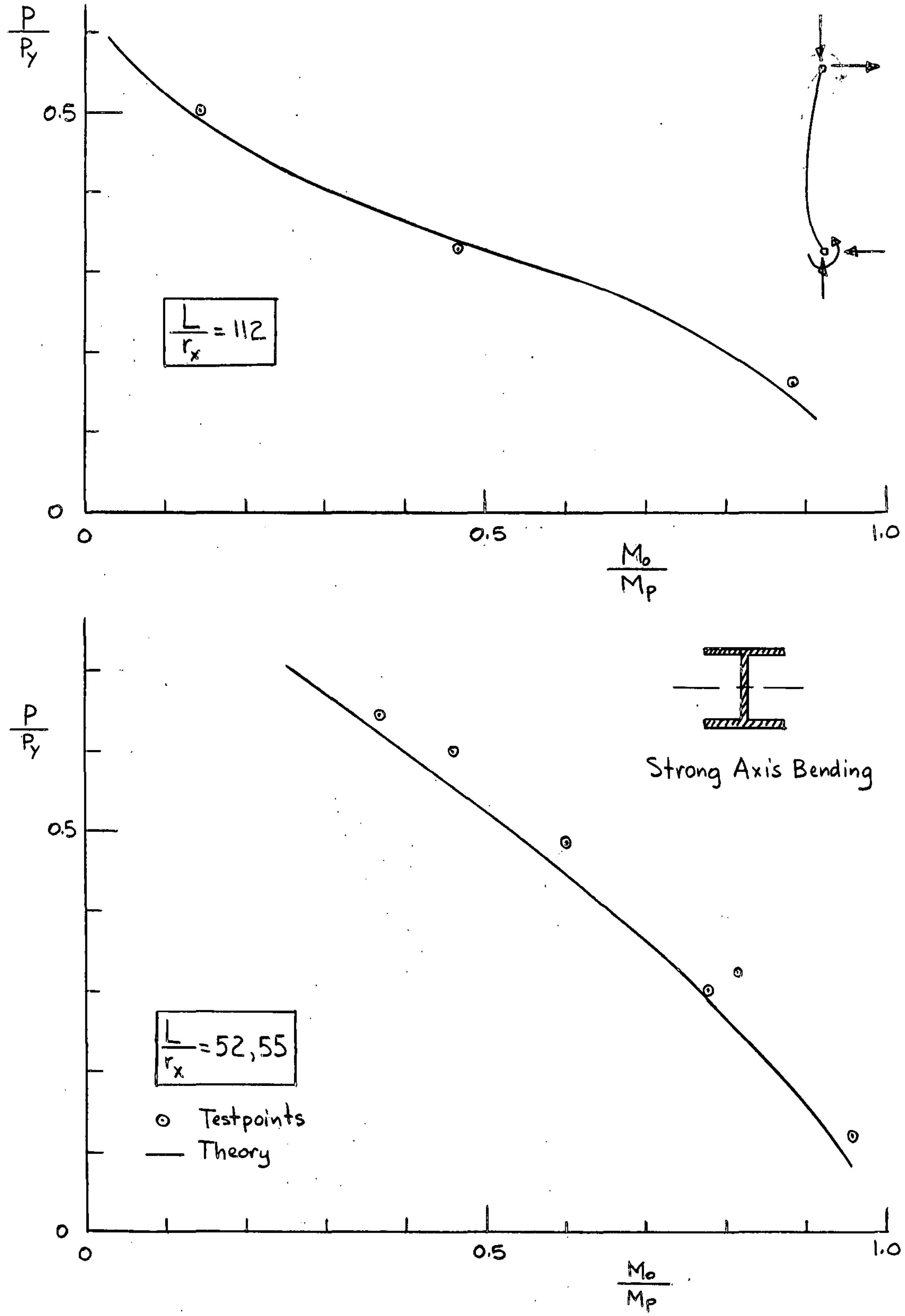


Fig. 1 COMPARISON OF COLUMN STRENGTH WITH THEORY

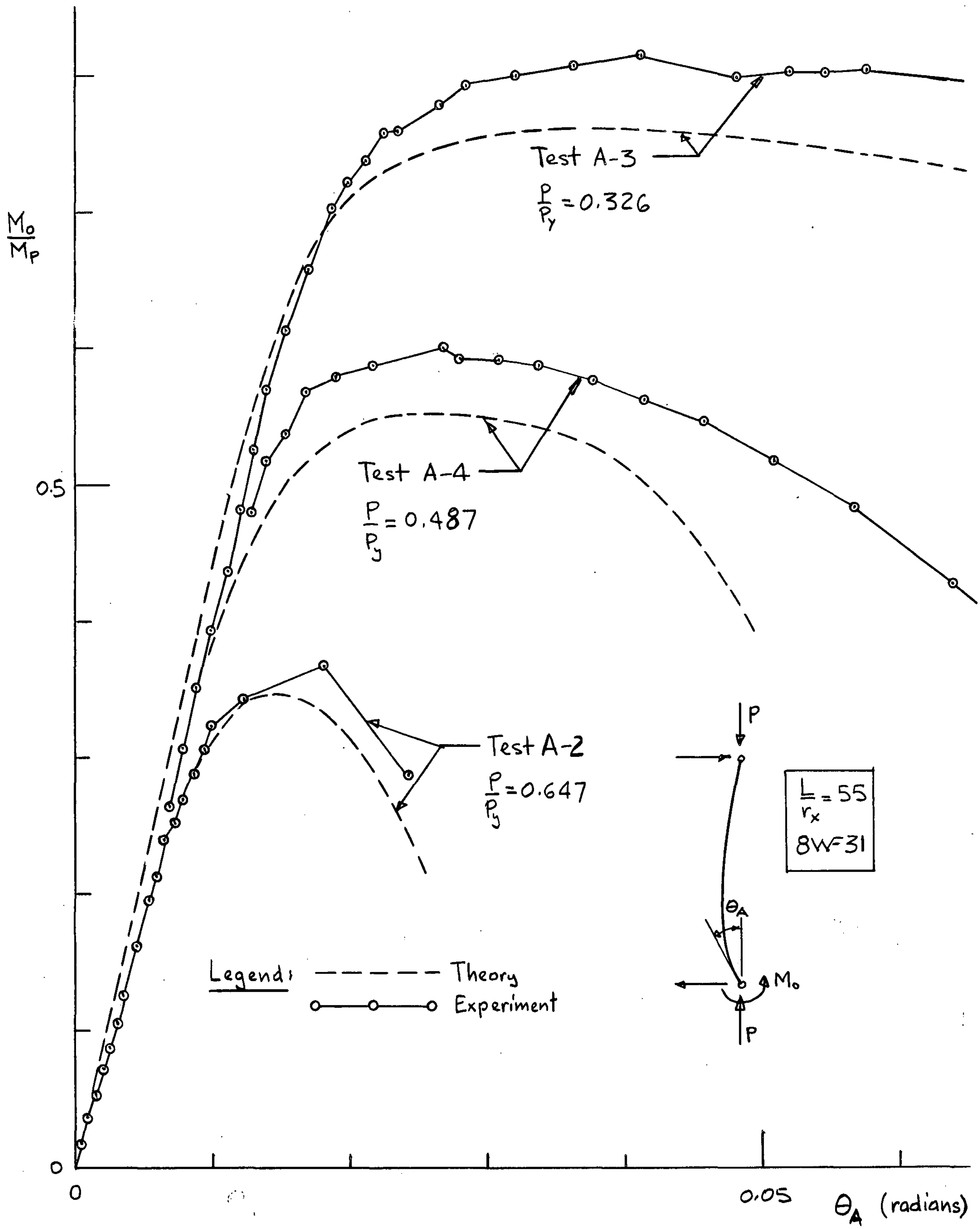
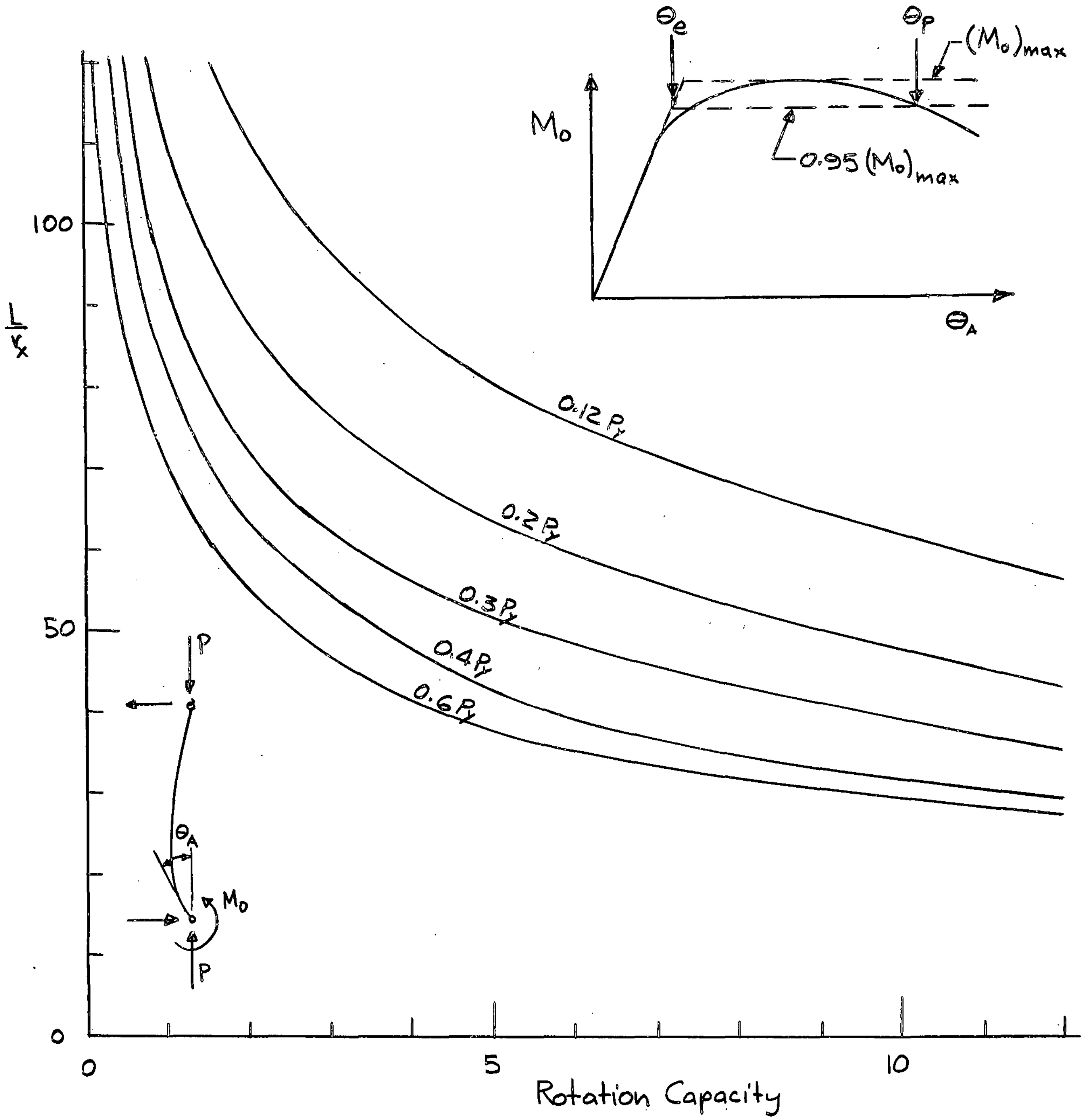


Fig. 2 THEORETICAL AND EXPERIMENTAL M-θ CURVES



Definition of Rotation Capacity: $\frac{\theta_p - \theta_e}{\theta_e}$

Fig. 3 VARIATION OF ROTATIONAL CAPACITY WITH P AND L FOR LOADING CASE "d"

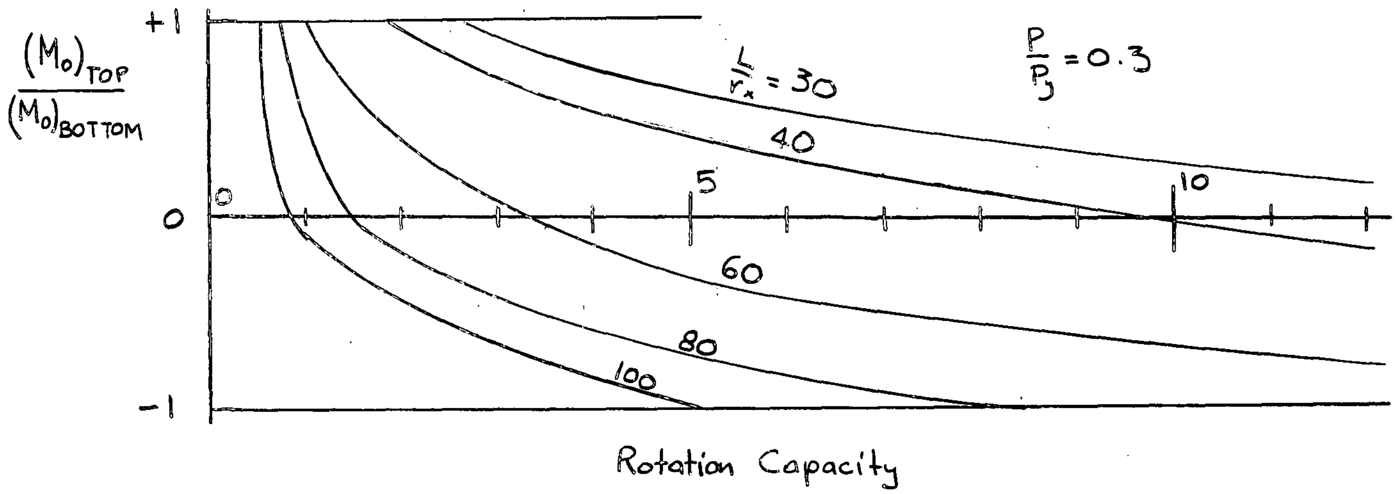


Fig. 4 VARIATION OF ROTATION CAPACITY WITH LOADING CONDITION AND LENGTH FOR $P = 0.3\ P_y$

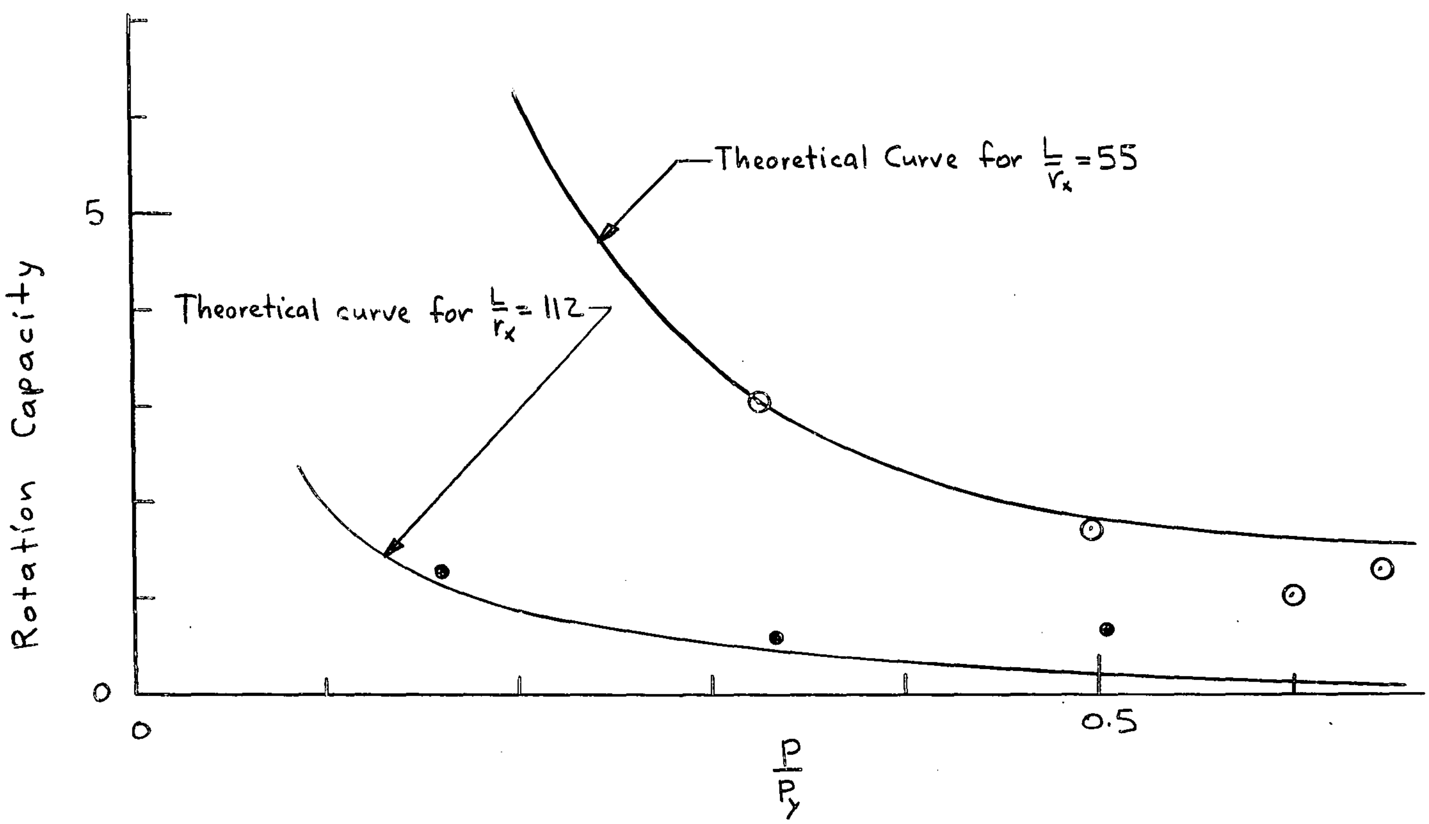


Fig. 5 COMPARISON OF EXPERIMENTAL ROTATION CAPACITY WITH THEORY