REPORT NO. FRA/ORD-80/25

TRACK COMPONENT PROPERTY TESTS
VOLUME II-RAIL, TIES, JOINT-BARS and FASTENERS

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INTERIM REPORT

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PREFACE

These tests were conducted under Task 3, Laboratory Testing, of Contract DOT-FR-30038, sponsored by the Federal Railroad Administration, Office of Research and Development, Improved Track Structures Research Division.

The principal objective of this laboratory test program is to investigate the load capacity of track in the vertical and lateral planes to support assessments of track strength.

The valuable suggestions of Mr. Howard Moody, Contracting Officer's Technical Representative of the Federal Railroad Administration, and Mr. Donald P. McConnell, Transportation Systems Center are gratefully acknowledged.

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1.0 INTRODUCTION

The objective of this phase of the laboratory test program was to determine physical and structural properties of typical track components used in railroad track systems.

The need for these track component properties became apparent during the development of analytical models for the description of the track system behavior, which was done under task 1 of the contract, and for the design and maintenance of track. It was found that required component property data was either unavailable or available but of questionable reliability.

In order to fill the voids in certain areas of basic component properties, and to clarify the existing results, a set of tests was conducted at the Association of American Railroad Track Laboratory at Chicago, Illinois. The majority of the tests were unique. However, in a few cases, tests which had been done previously were repeated to correct questionable data.

The results from these component property tests together with a description of the individual test set-up and procedures are described in this report. Along with Volume I (1), this report forms a data base of physical properties of track components used on the North American Railroads.

2.0 REQUIRED COMPONENT PROPERTIES

In identifying the track and components property test requirements, seven characteristics are considered necessary for an accurate description of the track structure. These characteristics are defined in Volume I (1). Of these seven characteristics, four are covered in this report, two were covered in Volume I (1), and the last one, soil properties, i.e. ballast, subballast and subgrade properties, will be covered in a separate report (2).

The component characteristics that are described in this report are:

1. Vertical bending stiffness of concrete ties;

2. Torsional rigidity of 115 RE and 136 RE rail sections

3. Vertical and lateral bending stiffness of 136 RE Joint-Bar.

4. Fastener resistance to rotation (with two rail sections, 115 RE and 136 RE)

    1. About the vertical axis

    2. About the lateral axis

    3. About the longitudinal axis

3.0 BENDING STIFFNESS OF CONCRETE TIES

3.1 Objectives

The objective of this test was to determine the bending stiffness (EI) of concrete ties. Additionally, the modulus of elasticity (E) of the reinforced concrete ties was determined and compared with known material values.

3.2 Test Procedure

Five different manufacturers' concrete ties were tested. Each tie was tested by simply supporting it in the supplemental test fixture (1), over an 8 foot span, and applying a vertical load at mid-span. The test set-up is shown in Figure 1.

Deflections of each tie were measured at 4 locations along the tie; mid-span, quarter-span, and two eighth-span points, Figure 2. Deflections were measured with cantilever beam type displacement transducers. Applied force was measured with a 3,000 psi pressure transducer installed in the hydraulic pressure line.

Vertical load was applied in 1,000 lb. increments to a maximum of 5,000 lbs. This loading cycle was repeated three times for each tie.

Measurements were taken to establish the tie cross-sectional area at each of the instrumented points so that the local moment of inertia could be subsequently

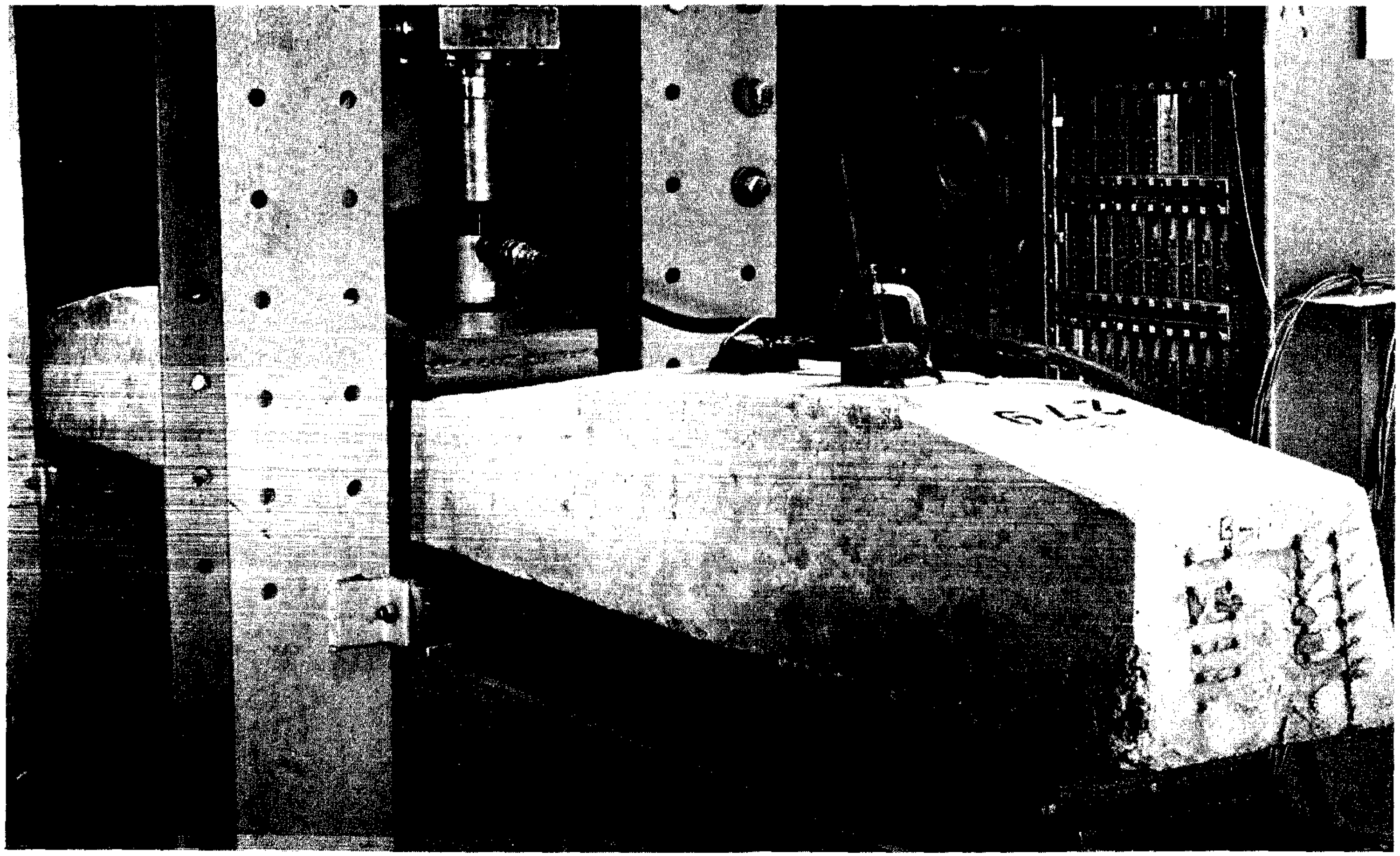
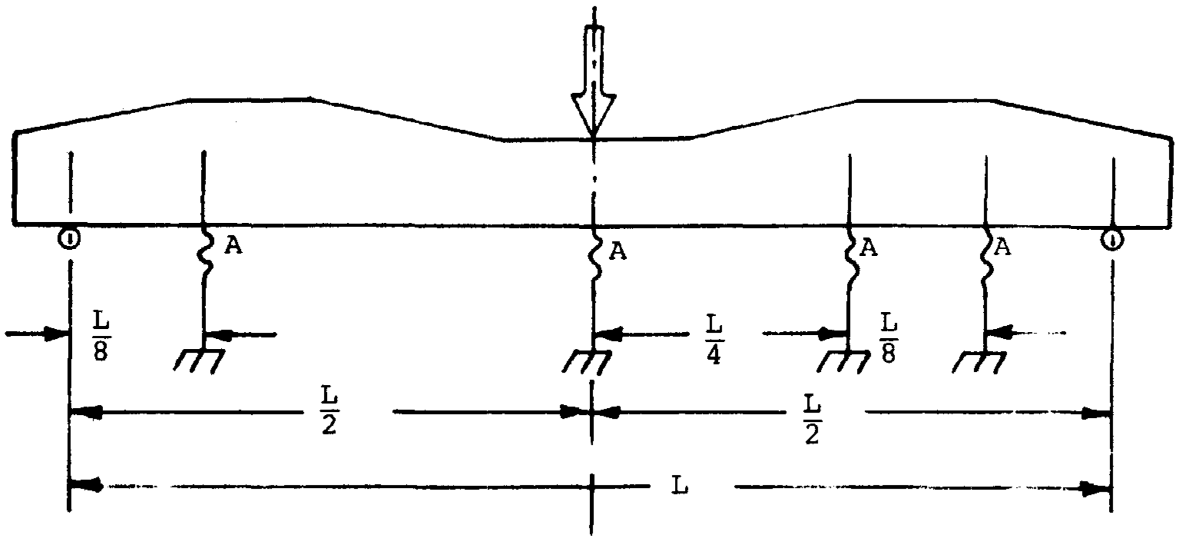


Figure 1. Test Set-Up for Bending Stiffness Test of Concrete Ties, Showing Loading Jack and Tie Supports.



L = 96 in. tie length = 102 in.

A - Bourns Model 80294 - 2" displacement transducers on tie centerline.

P - Force applied at center line of tie.

FIGURE 2. GENERAL ARRANGEMENT FOR ESTABLISHING BENDING STIFFNESS OF CONCRETE TIE.

calculated.

3.3 Results

The results of a typical tie vertical bending test are given in Table 1. The load and deflection at each measuring point and the calculated stiffness and stiffness modulus are given in the table.

The bending stiffness of the tie was determined from beam theory, for a simply supported beam, assuming uniform cross section area and using the relations:

$$EI = \frac{PL^3}{48d} \text{ at mid-span} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$EI = \frac{11PL^3}{768d} \text{ at } 1/4 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$EI = \frac{47PL^3}{6144d} \text{ at } 1/8 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

EI = Bending stiffness of tie ($lb\text{-}in^2$)

d = Deflection of the tie (inches)

L = Span length between simple supports (inches)

P = Applied load at mid-span (lbs)

Note, from Figure 3, the linearity of the load - deflection

TABLE 1. BENDING STIFFNESS OF CONCRETE TIES

	@ L/2			@ L/4			@ L/8			@ L/8		
LOAD (LB)	DEFLC. (IN)	EI $(LB-IN^2)$	E (PSI)	DEFLC. (IN)	EI $(LB-IN^2)$	E (PSI)	DEFLC. (IN)	EI $(LB-IN^2)$	E (PSI)	DEFLC. (IN)	EI $(LB-IN^2)$	E (PSI)
		TEST 243										
556.4	.0051	0.201E+10	0.569E+07	.0071	0.993E+09	0.157E+07	.0042	0.897E+09	0.125E+07	.0032	0.118E+10	0.164E+07
1139.6	.0094	0.223E+10	0.633E+07	.0143	0.101E+10	0.159E+07	.0072	0.107E+10	0.149E+07	.0060	0.129E+10	0.179E+07
1672.6	.0131	0.235E+10	0.666E+07	.0198	0.107E+10	0.169E+07	.0104	0.109E+10	0.152E+07	.0081	0.140E+10	0.195E+07
2248.6	.0173	0.240E+10	0.679E+07	.0265	0.108E+10	0.170E+07	.0133	0.114E+10	0.160E+07	.0106	0.144E+10	0.200E+07
2738.1	.0214	0.240E+10	0.680E+07	.0324	0.109E+10	0.172E+07	.0150	0.118E+10	0.164E+07	.0130	0.145E+10	0.202E+07
3341.9	.0258	0.239E+10	0.676E+07	.0392	0.111E+10	0.175E+07	.0186	0.122E+10	0.170E+07	.0153	0.148E+10	0.206E+07
3917.2	.0305	0.237E+10	0.670E+07	.0450	0.110E+10	0.174E+07	.0212	0.125E+10	0.174E+07	.0179	0.148E+10	0.206E+07
		TEST 243										
587.7	.0064	0.169E+10	0.479E+07	.0091	0.818E+09	0.129E+07	.0043	0.925E+09	0.129E+07	.0038	0.105E+10	0.146E+07
1126.6	.0113	0.184E+10	0.520E+07	.0153	0.933E+09	0.147E+07	.0090	0.847E+09	0.118E+07	.0076	0.100E+10	0.140E+07
1681.7	.0157	0.197E+10	0.559E+07	.0220	0.969E+09	0.153E+07	.0112	0.102E+10	0.142E+07	.0097	0.117E+10	0.164E+07
2244.0	.0197	0.210E+10	0.594E+07	.0233	0.100E+10	0.159E+07	.0154	0.986E+09	0.137E+07	.0130	0.117E+10	0.163E+07
2805.7	.0238	0.217E+10	0.615E+07	.0344	0.103E+10	0.163E+07	.0173	0.110E+10	0.153E+07	.0152	0.125E+10	0.174E+07
3345.2	.0283	0.218E+10	0.617E+07	.0406	0.104E+10	0.155E+07	.0211	0.107E+10	0.150E+07	.0175	0.129E+10	0.180E+07
3903.6	.0326	0.221E+10	0.625E+07	.0463	0.107E+10	0.169E+07	.0226	0.117E+10.	0.163E+07	.0198	0.133E+10	0.186E+07
		TEST 243										
598.1	.0064	0.172E+10	0.488E+07	.0093	0.815E+09	0.129E+07	.0043	0.941E+09	0.131E+07	.0038	0.107E+10	0.149E+07
1139.6	.0113	0.186E+10	0.526E+07	.0154	0.938E+09	0.148E+07	.0090	0.857E+09	0.119E+07	.0077	0.100E+10	0.140E+07
1592.8	.0155	0.201E+10	0.570E+07	.0215	0.998E+09	0.157E+07	.0109	0.105E+10	0.147E+07	.0095	0.121E+10	0.168E+07
2245.3	.0195	0.212E+10	0.601E+07	.0280	0.102E+10	0.160E+07	.0149	0.102E+10	0.142E+07	.0132	0.115E+10	0.161E+07
2791.3	.0235	0.219E+10	0.620E+07	.0339	0.104E+10	0.165E+07	.0164	0.115E+10	0.161E+07	.0154	0.123E+10	0.171E+07
3336.7	.0278	0.221E+10	0.626E+07	.0400	0.106E+10	0.167E+07	.0202	0.112E+10	0.156E+07	.0180	0.125E+10	0.175E+07
3910.7	.0325	0.222E+10	0.628E+07	.0455	0.109E+10	0.172E+07	.0219	0.121E+10	0.169E+07	.0204	0.130E+10	0.181E+07
		TEST 243										
585.1	.0063	0.171E+10	0.485E+07	.0091	0.815E+09	0.129E+07	.0044	0.900E+09	0.125E+07	.0036	0.110E+10	0.153E+07
1144.8	.0112	0.188E+10	0.533E+07	.0155	0.930E+09	0.147E+07	.0090	0.861E+09	0.120E+07	.0075	0.103E+10	0.144E+07
1598.0	.0153	0.205E+10	0.579E+07	.0221	0.974E+09	0.154E+07	.0133	0.864E+09	0.120E+07	.0097	0.118E+10	0.165E+07
2236.2	.0191	0.216E+10	0.611E+07	.0281	0.101E+10	0.159E+07	.0144	0.105E+10	0.147E+07	.0128	0.118E+10	0.165E+07
2735.5	.0233	0.220E+10	0.624E+07	.0347	0.102E+10	0.161E+07	.0186	0.101E+10	0.141E+07	.0153	0.123E+10	0.172E+07
3342.6	.0280	0.220E+10	0.623E+07	.0412	0.103E+10	0.162E+07	.0204	0.111E+10	0.155E+07	.0174	0.130E+10	0.181E+07
3908.8	.0323	0.223E+10	0.631E+07	.0470	0.105E+10	0.166E+07	.0240	0.110E+10	0.154E+07	.0199	0.133E+10	0.185E+07
		TEST 243										
592.9	.0063	0.173E+10	0.491E+07	.0089	0.844E+09	0.133E+07	.0043	0.933E+09	0.130E+07	.0036	0.111E+10	0.155E+07
1141.6	.0113	0.186E+10	0.527E+07	.0155	0.933E+09	0.147E+07	.0091	0.849E+09	0.118E+07	.0076	0.102E+10	0.142E+07
1599.9	.0151	0.208E+10	0.587E+07	.0218	0.988E+09	0.156E+07	.0116	0.992E+09	0.138E+07	.0097	0.119E+10	0.165E+07
2245.3	.0191	0.217E+10	0.613E+07	.0282	0.101E+10	0.159E+07	.0157	0.958E+09	0.135E+07	.0130	0.117E+10	0.163E+07
2788.7	.0233	0.221E+10	0.624E+07	.0344	0.103E+10	0.162E+07	.0172	0.110E+10	0.153E+07	.0153	0.123E+10	0.172E+07
3356.2	.0281	0.220E+10	0.623E+07	.0409	0.104E+10	0.164E+07	.0211	0.108E+10	0.150E+07	.0179	0.127E+10	0.177E+07
3914.0	.0326	0.221E+10	0.626E+07	.0466	0.106E+10	0.168E+07	.0224	0.118E+10	0.165E+07	.0200	0.132E+10	0.185E+07

AVERAGE STIFFNESS = 0.21012E+10
STANDARD DEVIATION OF THE SAMPLE = 0.20072E+09
STANDARD DEVIATION = 0.19733E+09

relationship for tie bending indicates that the use of linear elastic beam theory is valid.

Using the moment of inertia determined for each cross-section to determine modulus of elasticity from the tie stiffness, and averaging these values, the average modulus of elasticity was calculated for each tie and it is given in Table 2 along with the stiffness for all the ties tested.

The experimental values of the modulus of elasticity fall above the range of the modulus for concrete, 5.38 x 10E+6 lb/in- (3). This was expected since all the ties tested were reinforced with steel, thus the effective modulus of the composite had to be higher than for plain concrete.

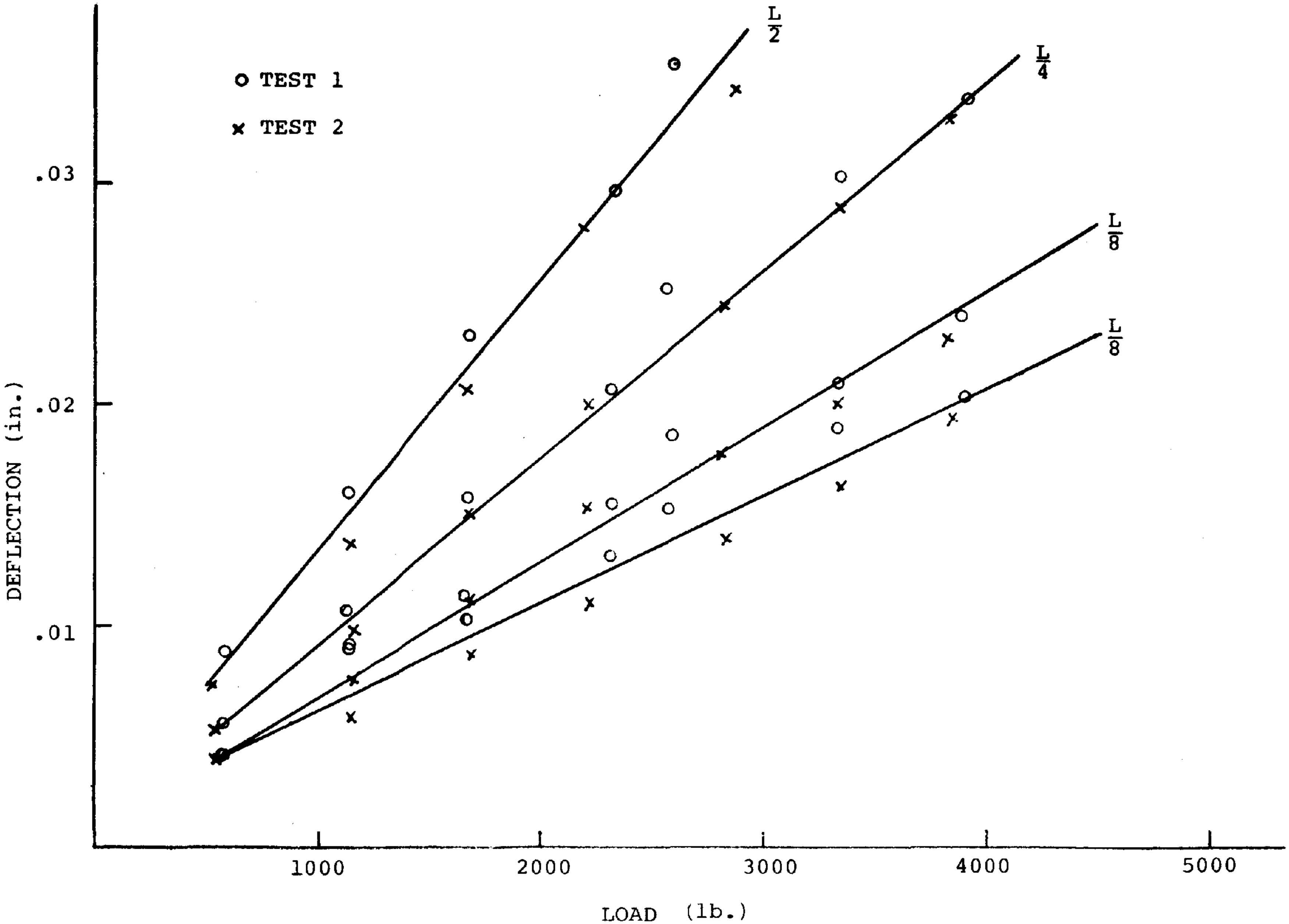


Figure 3. Tie Deflections vs Load for Two Tests From the Concrete Tie Bending Stiffness Test Series.

TABLE 2: AVERAGE BENDING STIFFNESS OF CONCRETE TIES, ALONG WITH THE CALCULATED MOMENT OF INERTIA AND MODULUS OF ELASTICITY.

TIE	BENDING STIFFNESS X 10E8 ($LB\text{-}IN^2$)	MOMENT OF INERTIA @ MID-POINT (IN^4)	MODULUS ELASTICITY X 10E6 (LB/IN^2)
A	20.30	353.0	5.75
B	15.97	289.4	5.51
C	15.97	289.4	5.57
D	14.29	277.1	5.39
E	15.12	283.7	5.32
F	11.61	155.9	7.41

A = Dow-Mac
B = Grinaker G-23
C = Westinghouse BW-2
D = Con Force Costain CC244C
E = Santa Fe Pomreoy RT-7SS
F = Santa Fe Pomreoy RT-7

Note that the stiffness given in this table is the average stiffness taken from the five tests.

4.0 TORSIONAL RIGIDITY OF RAIL

4.1 Objectives

The objective of this test was to determine experimentally the torsional rigidity of 115 RE and 136 RE rail sections.

4.2 Test Procedure

A 32 inch length of rail was used for this test. Two 30 X 12 inch steel plates, one inch thick, were welded to both ends of the rail in such a way that the center of the plates were coincident with the calculated shear center of the rail section. The length of rail was then placed in the test fixture by bolting one end to the fixture column and keeping the other end free, as show in Figure 4.

Two deflection measurments were taken at the free end of the steel plate. The instruments were placed 10 inches apart and one inch from the end of the plate. Two 2 inch deflection transducers were used to measure deflections and a 3,000 psi pressure transducer in the hydraulic line was used to measure the applied jack forces. The deflection transducers and load application arrangement points are illustrated in Figure 5.

A force couple was applied to the free end of the rail by means of two loading jacks (Figure 5). The magnitude of the couple was controlled and was applied incrementaly at one Kip increments from one to five kips of force. The

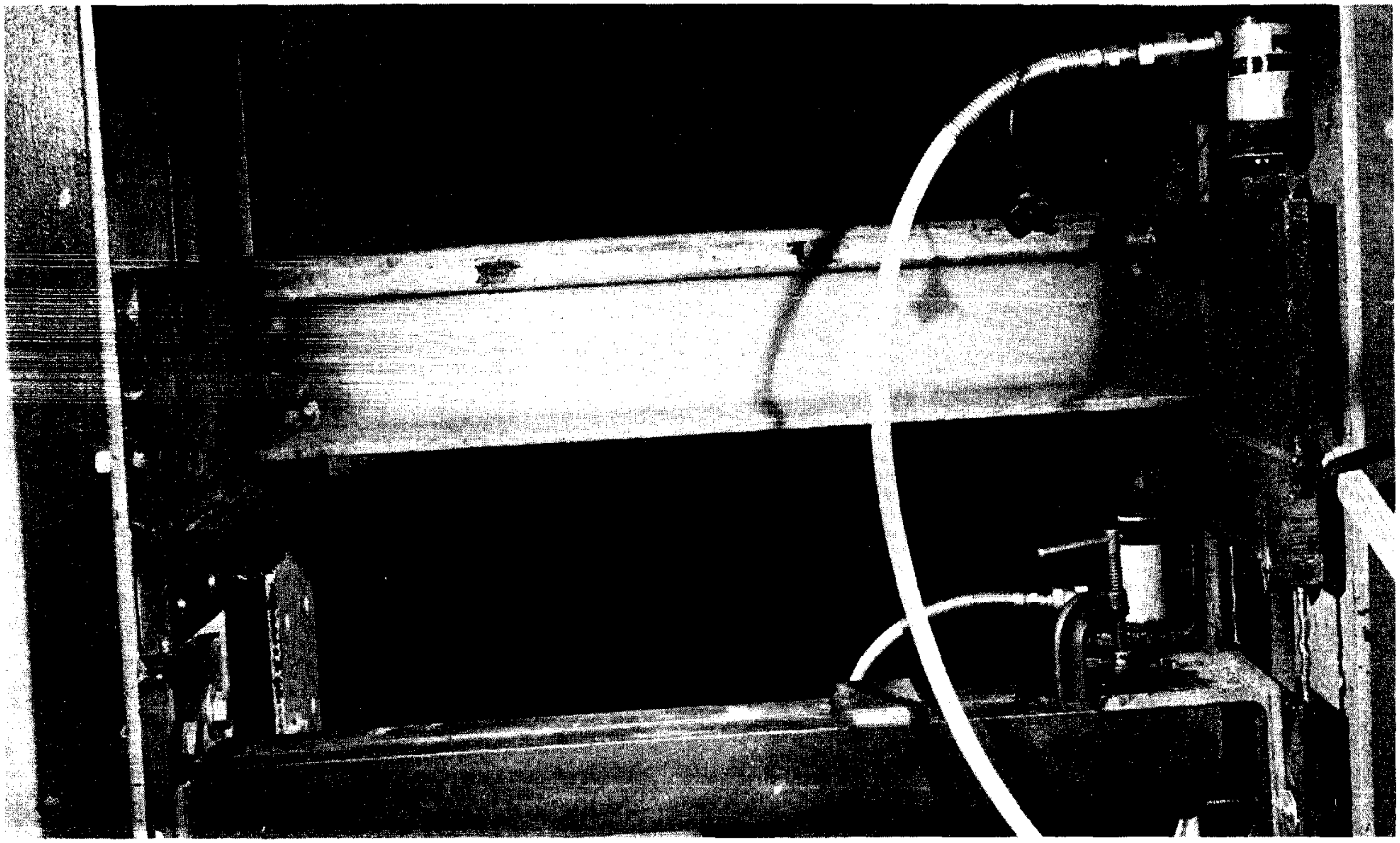


Figure 4. Test Set-Up for Rail Torsional Resistance Tests, Showing the Fixed Support, Loading Jacks and Instrumentation.

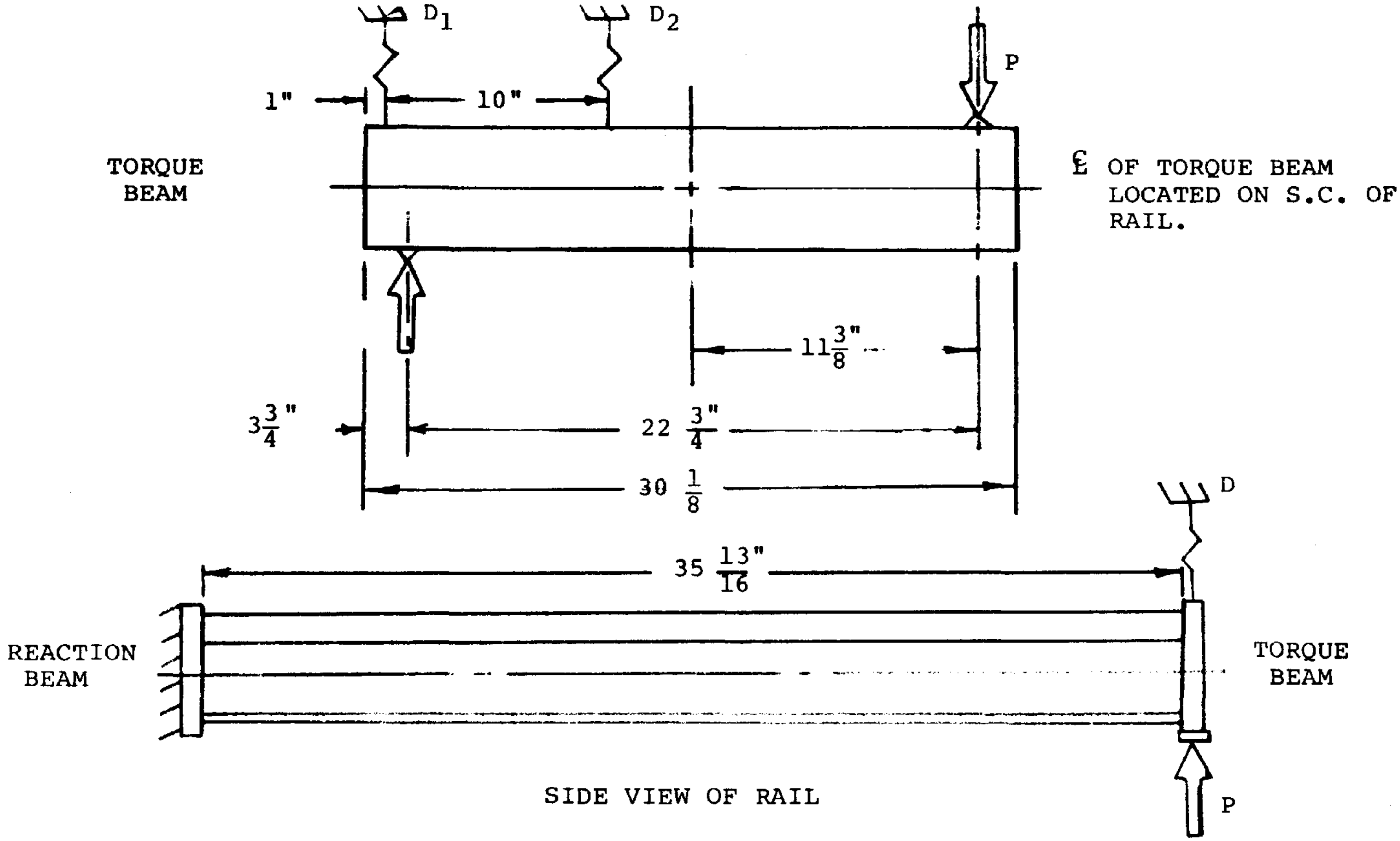


Figure 5. Arrangement for Determining
Torsional Stiffness
136 RE Rail Section.

loading cycle was repeated five times for each rail section*.

The above described procedure was then repeated for the 136 RE rail section. Data was recorded on both magnetic and paper tape and reduced in accordance with the procedure given in Appendix A of Reference (1)

4.3 Results

The results from the torsional rigidity tests are given in Table 3 for the 115 RE rail section and Table 4 for the 136 RE rail section.

The torsional rigidity of the rail was determined using Coulomb's theory of torsion for non-circular members (4)

$$GJ = \frac{TL}{F} \qquad \text{.............................(4)}$$

Where GJ is the torsional rigidity (lb.-in.^{2}/radian)

G is the shear modulus (lb./in.^{2})

J is the polar moment of inertia (in.^{4})

T is the applied torque (in.-lb.)

L is the length of the section (in.)

F is the angle of twist (radian)

* Note that the couple was applied through the calculated shear center of the rail and it was checked with Moire Patterns (5). In both rail sections it was confirmed in this manner that the couple was applied through the shear center of the rail section.

TABLE 3.TORSIONAL RIGIDITY OF 115 RE RAIL SECTION.

TORQUE (LB-IN)	DEFLECTIONS (IN) LOC 1	LOC 2	TWIST ANGLE (RADIAN)	STIFFNESS X 10E+6 (LB-IN/RADIAN)
6556.43	0.0160	0.0902	0.7420	31.64550
8817.04	0.0231	0.1242	1.0110	31.23395
11143.94	0.0291	0.1579	1.2879	30.98757
13265.33	0.0346	0.1896	1.5499	30.65221
15519.31	0.0403	0.2221	1.8178	30.57504
17786.55	0.0467	0.2564	2.0967	30.38068
20073.67	0.0550	0.2896	2.3456	30.64920
		TEST 2		
6622.72	0.0220	0.0919	0.6990	33.93181
8777.26	0.0287	0.1240	0.9530	32.98526
11004.72	0.0343	0.1563	1.2199	32.30587
13404.55	0.0403	0.1920	1.5169	31.64758
15764.59	0.0472	0.2285	1.8128	31.14392
17985.43	0.0538	0.2615	2.0767	31.01611
19980.86	0.0605	0.2915	2.3096	30.98276
		TEST 3		
6622.72	0.0215	0.0908	0.6930	34.22558
8929.73	0.0281	0.1250	0.9690	33.00419
11037.87	0.0326	0.1545	1.2189	32.42976
13232.18	0.0378	0.1868	1.4899	31.80666
15459.64	0.0453	0.2215	1.7618	31.42529
17713.62	0.0516	0.2562	2.0457	31.01009
19934.46	0.0584	0.2901	2.3166	30.81745
		TEST 4		
6549.80	0.0217	0.0904	0.6870	34.14434
8836.92	0.0283	0.1245	0.9620	32.89881
11071.01	0.0349	0.1575	1.2259	32.34144
13238.81	0.0399	0.1900	1.5009	31.58942
15479.53	0.0465	0.2248	1.7828	31.09519
17786.55	0.0536	0.2619	2.0827	30.58482
20106.82	0.0611	0.2969	2.3576	30.54364
		TEST 5		
6715.53	0.0225	0.0917	0.6920	34.75537
8909.85	0.0281	0.1235	0.9540	33.44843
11037.87	0.0326	0.1539	1.2129	32.59015
13530.50	0.0396	0.1908	1.5119	32.05058
15585.60	0.0448	0.2231	1.7828	31.30826
17779.92	0.0518	0.2579	2.0607	30.89968
20020.64	0.0573	0.2897	2.3236	30.85749

TORSIONAL RIGIDITY = 0.31828E+08
STANDARD DEVIATION = 0.12030E+07

TABLE 4. TORSIONAL RIGIDITY OF 136 RE RAIL SECTION

TORQUE (LB-IN)	DEFLECTIONS (IN) LOC 1	DEFLECTIONS (IN) LOC 2	TWIST ANGLE (RADIAN)	STIFFNESS X 10E+6 (LB-IN/RADIAN)
6695.64	0.0106	0.0618	0.5120	46.83461
8929.73	0.0142	0.0836	0.6940	46.08152
11130.68	0.0186	0.1059	0.8730	45.66244
13344.88	0.0237	0.1273	1.0360	46.13295
15472.90	0.0315	0.1537	1.2219	45.34850
18031.83	0.0394	0.1837	1.4429	44.75529
20279.18	0.0458	0.2084	1.6259	44.66927
		TEST 2		
6695.64	0.0098	0.0577	0.4790	50.06115
8929.73	0.0136	0.0795	0.6590	48.52886
11137.31	0.0188	0.1037	0.8490	46.98115
13510.62	0.0251	0.1288	1.0370	46.66085
15545.83	0.0329	0.1523	1.1939	46.63058
17952.28	0.0398	0.1799	1.4009	45.89344
20226.15	0.0460	0.2033	1.5729	46.05332
		TEST 3		
6682.38	0.0095	0.0572	0.4770	50.17150
8982.77	0.0141	0.0814	0.6730	47.80160
11203.60	0.0193	0.1050	0.8570	46.81965
13470.84	0.0253	0.1287	1.0340	46.65845
15658.52	0.0330	0.1534	1.2039	46.57856
18045.09	0.0400	0.1801	1.4009	46.13070
20239.41	0.0464	0.2031	1.5669	46.25993
		TEST 4		
6715.53	0.0094	0.0575	0.4810	50.00108
9049.06	0.0140	0.0825	0.6850	47.31083
11236.75	0.0195	0.1057	0.8620	46.68580
13437.69	0.0251	0.1289	1.0380	46.36429
15671.78	0.0326	0.1533	1.2069	46.50214
18038.46	0.0402	0.1813	1.4109	45.78698
20285.81	0.0473	0.2040	1.5669	46.36600
		TEST 5		
6781.83	0.0093	0.0576	0.4830	50.28559
9022.55	0.0138	0.0820	0.6820	47.37968
11243.38	0.0195	0.1052	0.8570	46.98587
13583.54	0.0255	0.1300	1.0450	46.55358
15618.75	0.0335	0.1539	1.2039	46.46024
17978.80	0.0400	0.1805	1.4049	45.83039
20246.03	0.0466	0.2034	1.5679	46.24558

TORSIONAL RIGIDITY = 0.46842E+08
STANDARD DEVIATION = 0.14063E+07

The average torsional rigidity of the rail section was found to be 31.82 x 10E+6 lb.-in /radian for 115 RE rail section and 46.84 x 10E+6 lb.-in./radian for the 136 RE rail section. These values are 48% lower than the theoretical values given by Perlman (6), 47.21 lb.-in. /radian for 115 RE rail and 69.54 lb.-in./radian for 136 RE rail.

5.0 JOINT-BAR BENDING STIFFNESS

5.1 Objectives

The objective of this test series was to determine the rotational stiffness of a joint under various bolt tensioning loads in the vertical and lateral planes. Specific items to be determined are: rotational joint stiffness (k) in the vertical and lateral planes with bolt tensions of 20,000 lb., 12,000 lb. and 4,000 lb.

5.2 Test Procedures

Two lengths of standard carbon 136 RE rail were joined together with joint bars as described in the AREA Manual for Railway Engineering (7). The joined rails were supported in the test fixture as a simply supported beam with the supports directly under the end bolts of the joint-bar. This arrangement provided a 30 inch span.

Three load increments in each plane were applied at midspan of the rail joint with a hydraulic jack, for each bolt tension. The loads were measured with a pressure transducer installed in the hydraulic line.

Rail deflections were measured at five locations. One was taken at midspan and the other four were taken at the location of the four bolts, Figure 6. The deflections were measured with strain gaged cantilever beam type displacement transducers.

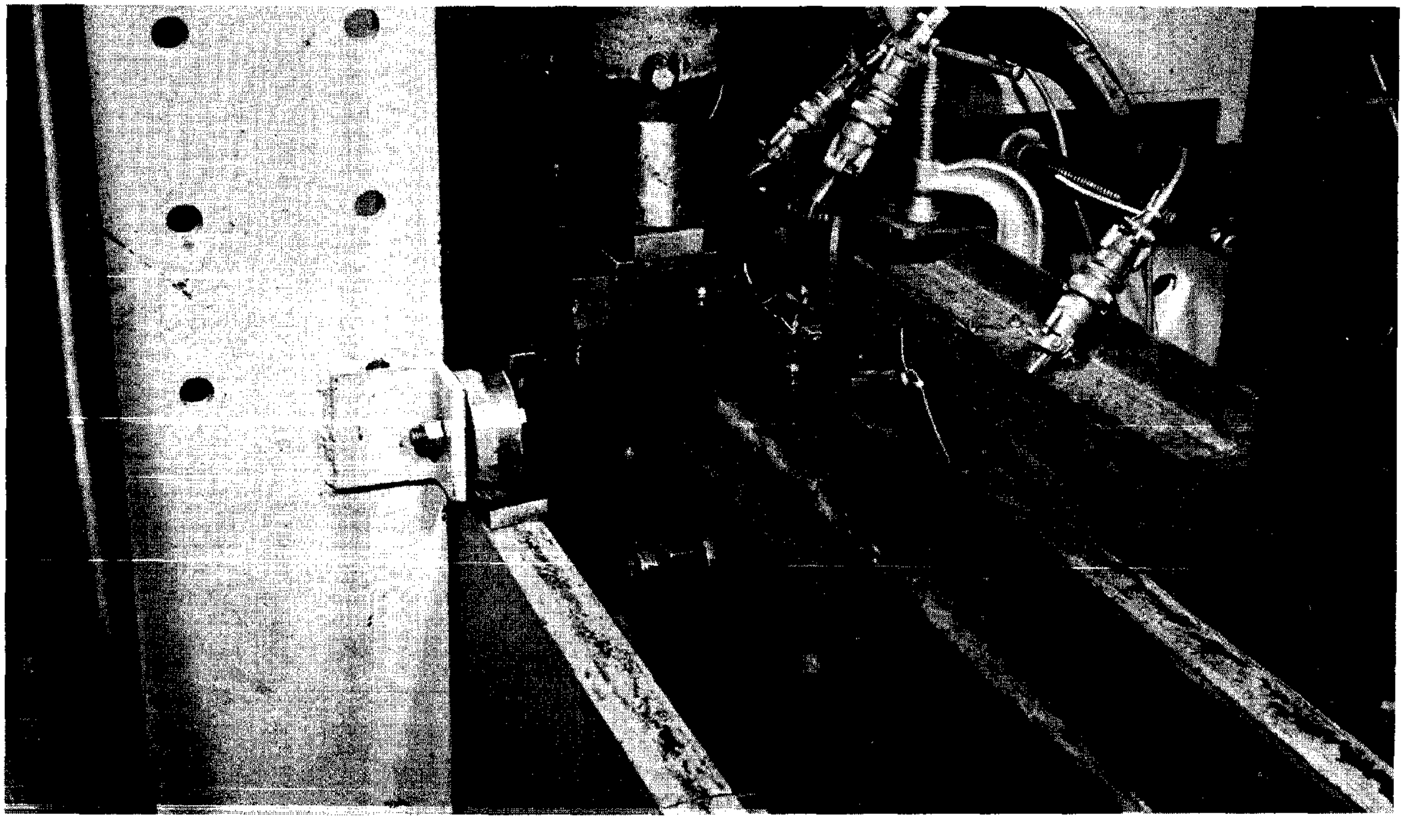


Figure 6. Test Set-Up for Joint-Bar Rotational Stiffness Tests, Showing the Loading Jack and Instrumentation.

Once the instrumentation was checked out, the load was applied and a data reading taken. Then the load was increased to the next increment and another reading taken. This procedure was followed until all the tests were completed.

5.3 Results

The joint-bar stiffness was calculated by modeling the system as two rails joined by a spring and simply supported as a beam. The stiffness of the joint-bar was taken to be the same stiffness as the spring. With this model and using simple beam theory, the stiffness of the joint-bar is equal to:

$$k = \frac{M}{\left| y'(l) - y'(l) \right|} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where k is the joint bar rotational stiffness ((in.-lb.)/rad)

y'(l) is the slope of the deflection curve

M is the applied moment (in.-lb.)

Using Bernoulli's beam equation and equation (5) the stiffness of the joint is equal to:

$$k = \frac{M}{f} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Were

$$f = \frac{Pl^2}{3EI} - \frac{2d}{l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$M = 0.50Pl \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

and

f is rotational angle (radians)

d is the rail deflection at mid-span (in.)

l is the length of the span (in.)

EI is the stiffness of the joint bar and rail (lb.-in.^{2})

P is the applied load (lb.)

M is the moment at mid-span (lb.-in.)

In a similar manner, the stiffness in the lateral plane was determined for both rail sections and are given in Table 5 for the three bolt tensioning loads tested. The results indicate that the bolt tension does not affect the rotational stiffness of the joint in the vertical plane. There is approximately 2% change in the rotational stiffness for bolt tensioning loads of 4,000 lb. to 20,000 lb.. However in the lateral plane the difference is substantial, approximately 34% increase in the rotational stiffness with a change of 16,000 lbs. in tensioning load on the bolts.

TABLE 5 JOINT-BAR ROTATIONAL STIFFNESS FOR 136 RE RAIL JOINT.

BOLT TENSION (LB)	ROTATIONAL STIFFNESS (LB-IN/RADIAN) X 10E+6
VERTICAL PLANE	
4000	29.43
12000	29.94
20000	30.04
LATERAL PLANE	
4000	16.83
12000	18.19
20000	22.52

6.0 FASTENER RESISTANCE TO ROTATION ABOUT THE PRINCIPAL AXES

6.1 Objectives

The objectives of this test series were to determine the resistance of several different fastener configurations to rotation of the rail about the three principal axes. These values were to be obtained for two rail sizes, 115 RE and 136 RE, for the following tie-fastener configurations:

1. Wood Tie - 2 cut spikes per plate
2. Wood Tie - 4 cut spikes per plate
3. Wood Tie - Pandrol fastener with 2 lock spikes
4. Wood Tie - Screw spikes
5. Wood Tie - Compression clip

Values for one rail section, 136 RE, were to be obtained for the following tie-fastener configurations:

1. Concrete Tie - Pandrol fastener
2. Concrete Tie - Compression clip

6.2 Test Procedure

For the fastener configuration on wood ties, a 30 inch length of rail was mounted on a 51 inch length of hard wood tie, with the fastener configuration under investigation and with the appropriate tie plate.

6.2.1 Z-Axis

The rail-tie segment was mounted in the test fixture, as shown in Figure 7. A torsional load about the vertical (Z) axis, i.e., in the plane of the tie, was applied. Deflections were measured using deflection transducers at the base of the rail, in two locations. The applied load was measured with a pressure transducer in the hydraulic line. A typical arrangement of loading jacks and deflection transducers is shown in Figure 8.

The torsional load was applied as a couple by two opposing lateral jacks located 11-3/8 inches from the center of the fastening system on opposite sides of the rail. The load was applied in 2000 in.-lbs increments until a rail base displacement of 0.25 inch was recorded. At the conclusion of the loading cycle, the tie and fastener were replaced and the test repeated. For each fastener configuration and rail section, this test series was repeated three times. Each test utilized a new tie segment and new fasteners.

6.2.2 Y-Axis

For the torsional resistance about the lateral (Y) axis, i.e. in the plane of the rail, the same type of instruments and procedures were followed as described above. The exception to this was that the torsional load was

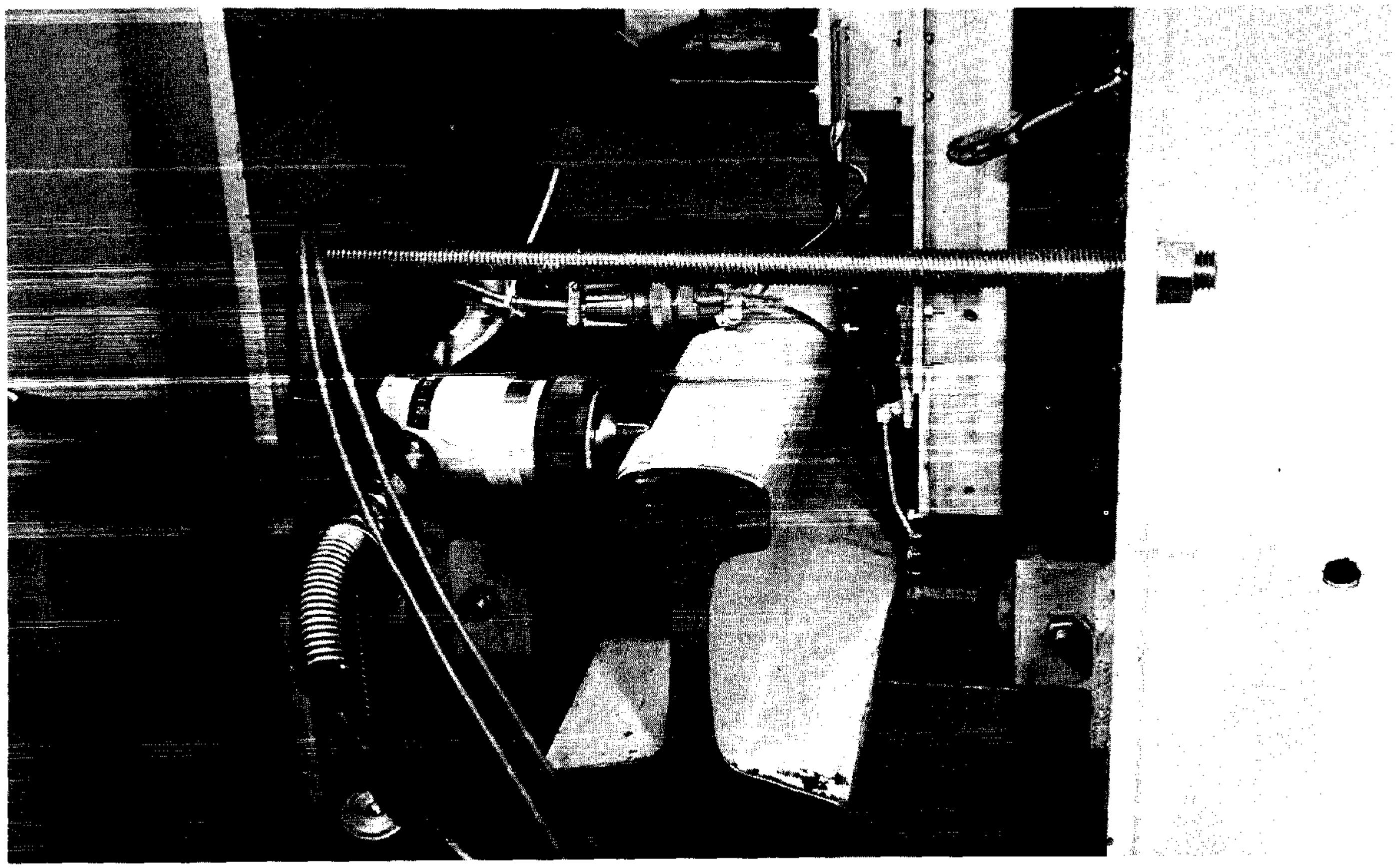


Figure 7. Test Set-Up for Fastener Resistance Test on Wood Ties About the Vertical Axis, Showing Load Application Arrangement and Instrumentation.

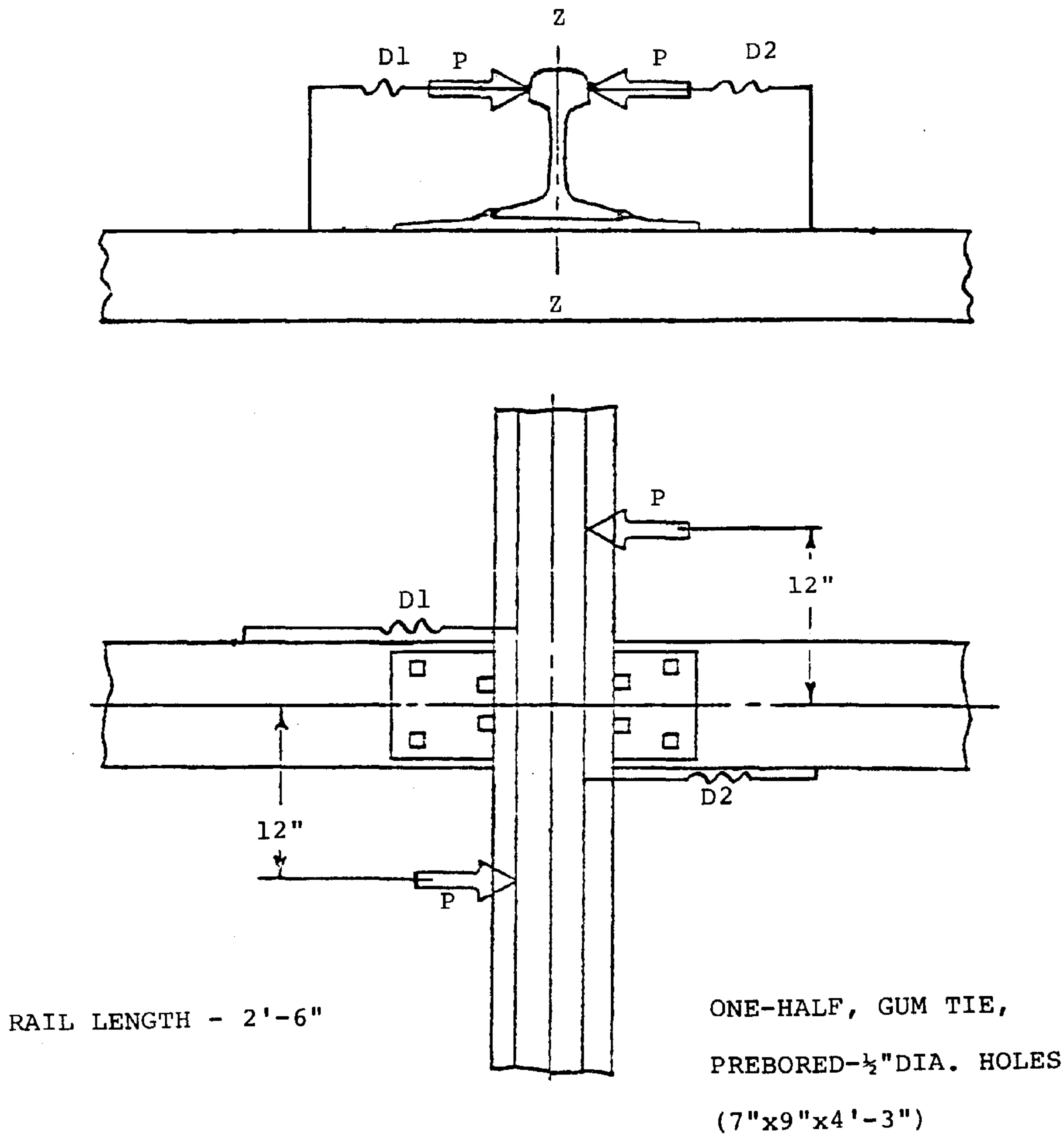


Figure 8. Fastener Stiffness Test About Vertical Axis

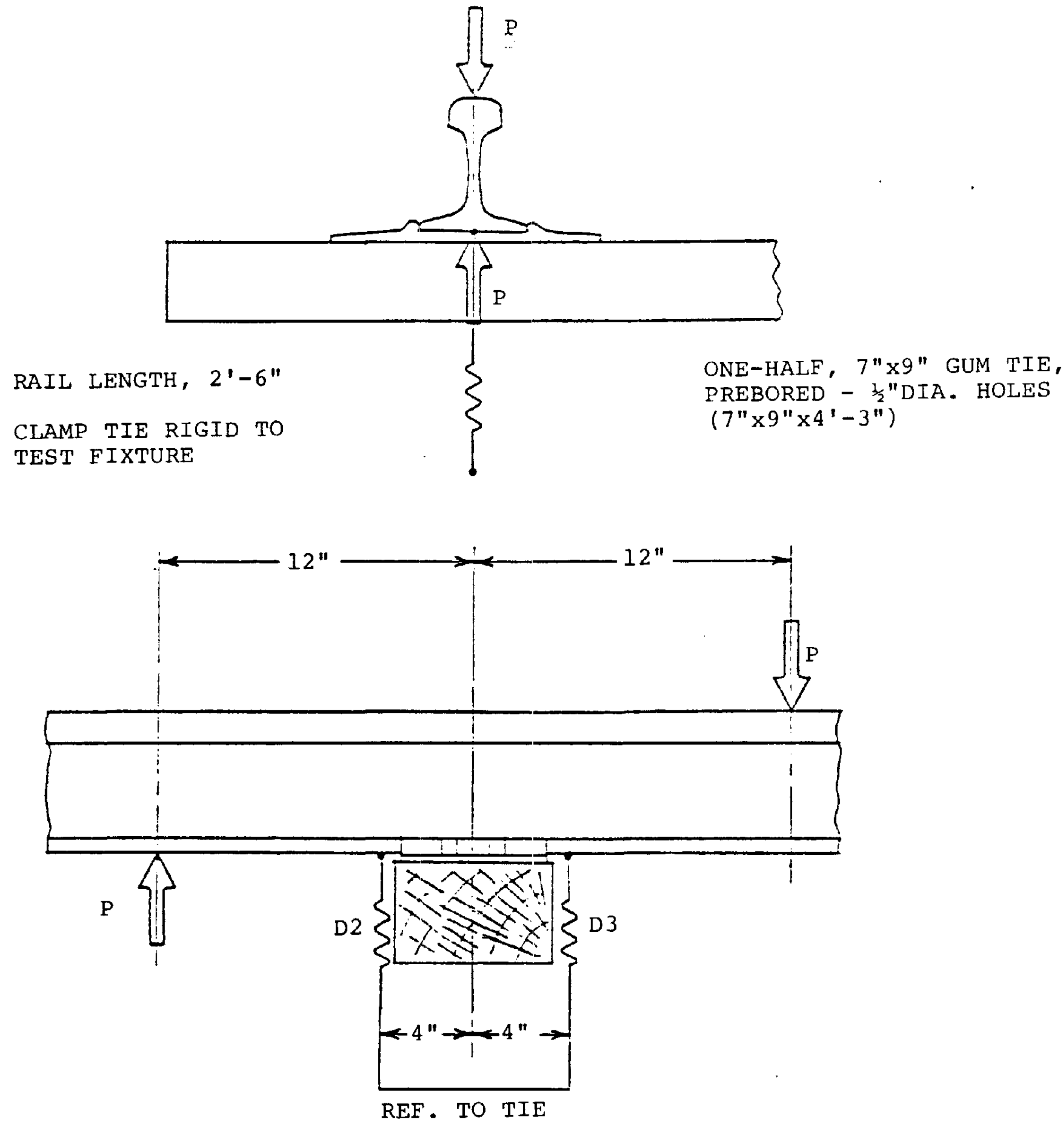


Figure 9. Fastener Stiffness Test About Lateral Axis

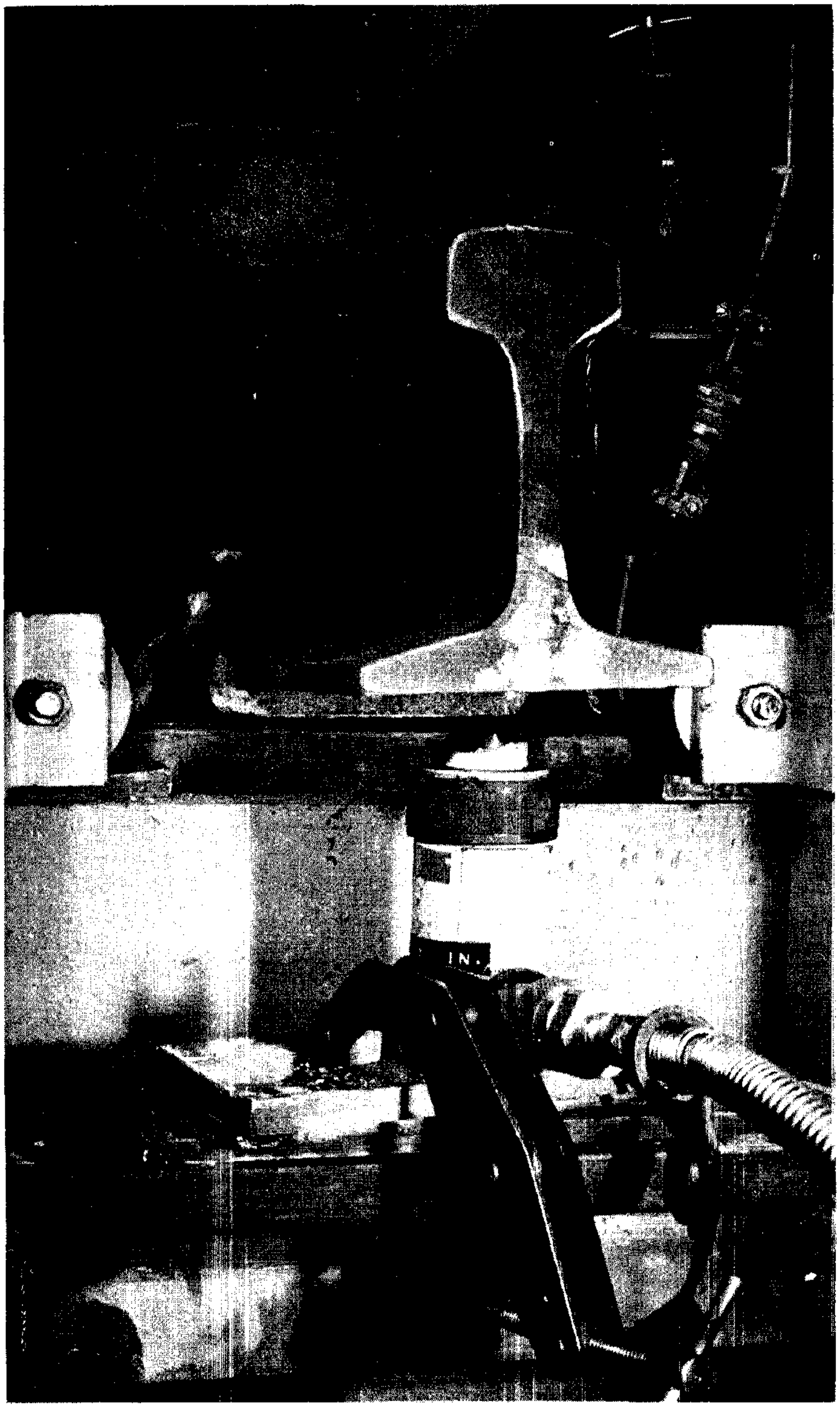


Figure 10. Test Set-Up for Fastener Resistance Test on Wood Ties About the Lateral Axis, Showing Load Application Arrangement and Instrumentation.

applied in the vertical plane and deflections were measured in the same plane, as shown in Figure 9. Typical arrangement of a test from this series is shown in Figure 10.

6.2.3 X-Axis

Torsional resistance about the longitudinal (x) axis, i.e. in the plane of the track, was tested in the same fixture used for the other two axis. Once the rail-tie segment was mounted the instrumentation and loading jack was placed as shown in Figure 11. Three channels of deflection data were taken, two were measured at the rail base each located 6 inches from the center of the fastening system and one was taken at the rail head opposite the applied lateral load. The lateral load was applied to the system using a loading jack at the gage point of the rail head and located at the center of the fastening system. The loads were applied in increments (depending on the type of fastener configuration used) until 0.25 inches of rail head displacement was noted. The location of the instruments and loading jacks is shown in Figure 12.

The concrete tie fastener configurations for each of the three principal planes were tested in the same test fixture, except for the longitudinal axis which was tested outside the test fixture. Loadings and deflection measurements were the same as those used for the wood ties. Figures 13, 14 and 15 show typical tests on concrete ties

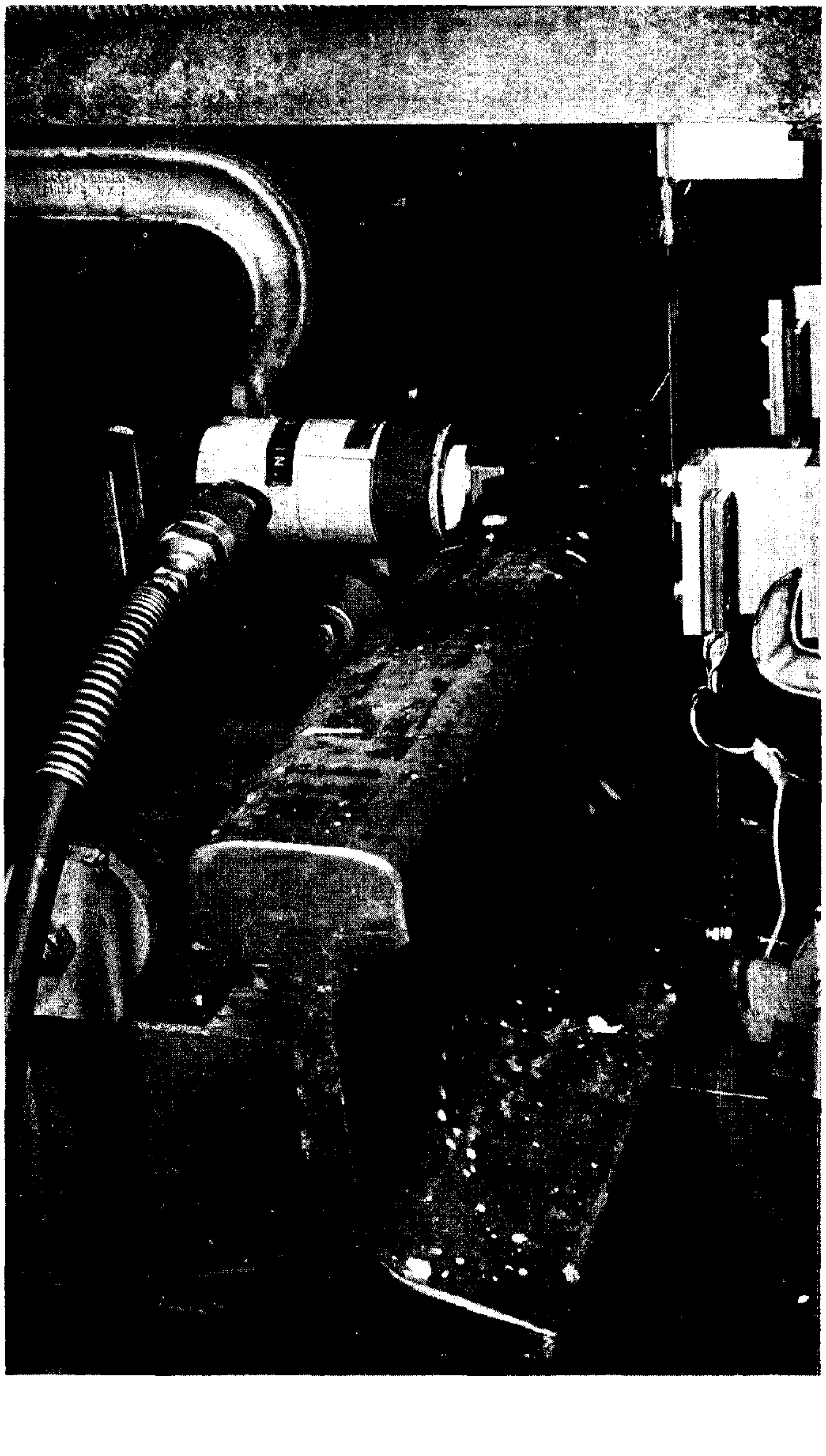


Figure 11, Test Set-Up for Fastener Resistance Test on Wood Ties About the Longitudinal Axis, Showing Load Application Arrangement and Instrumentation.

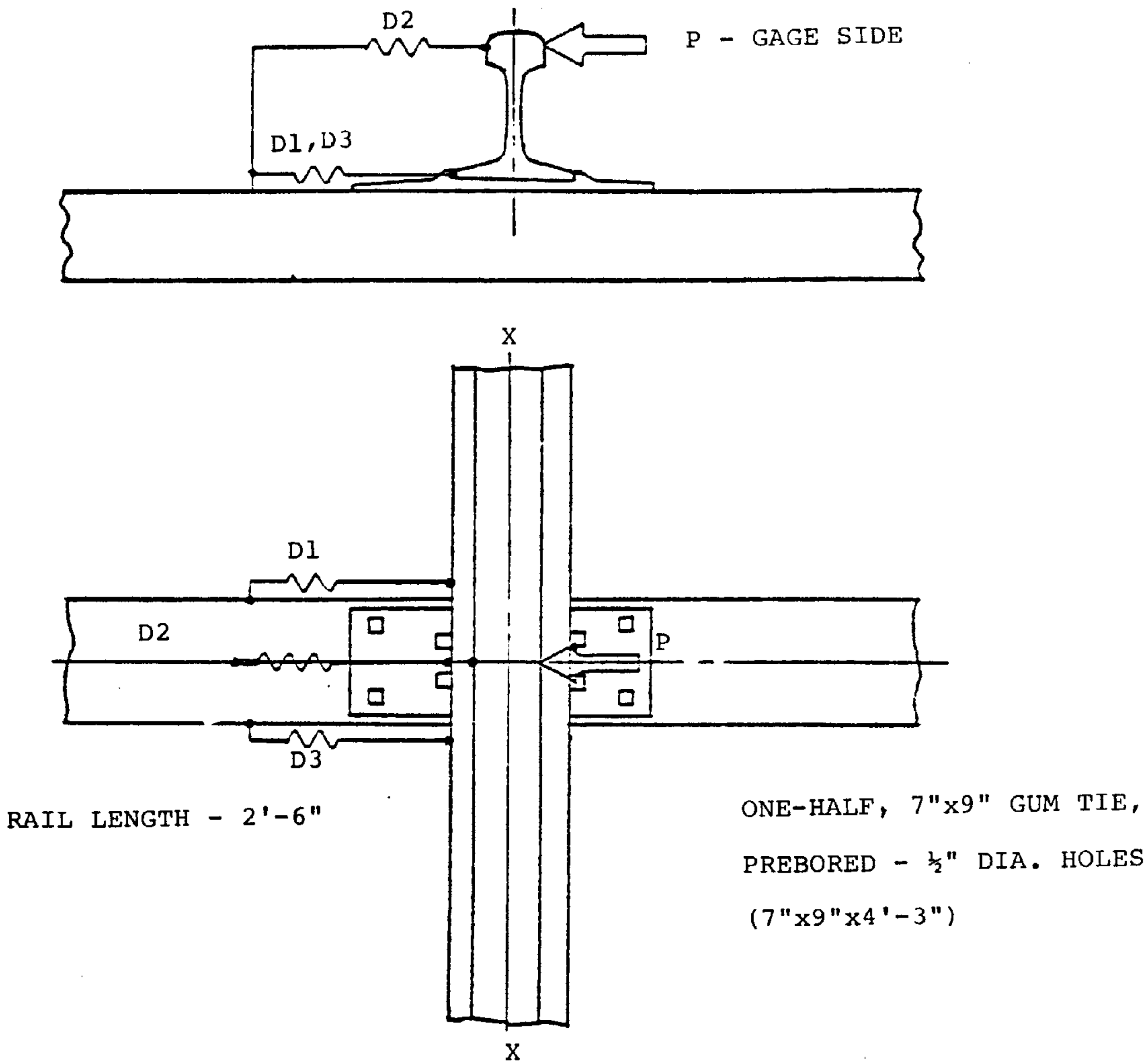


Figure 12. Fastener Stiffness Test About Longitudinal Axis

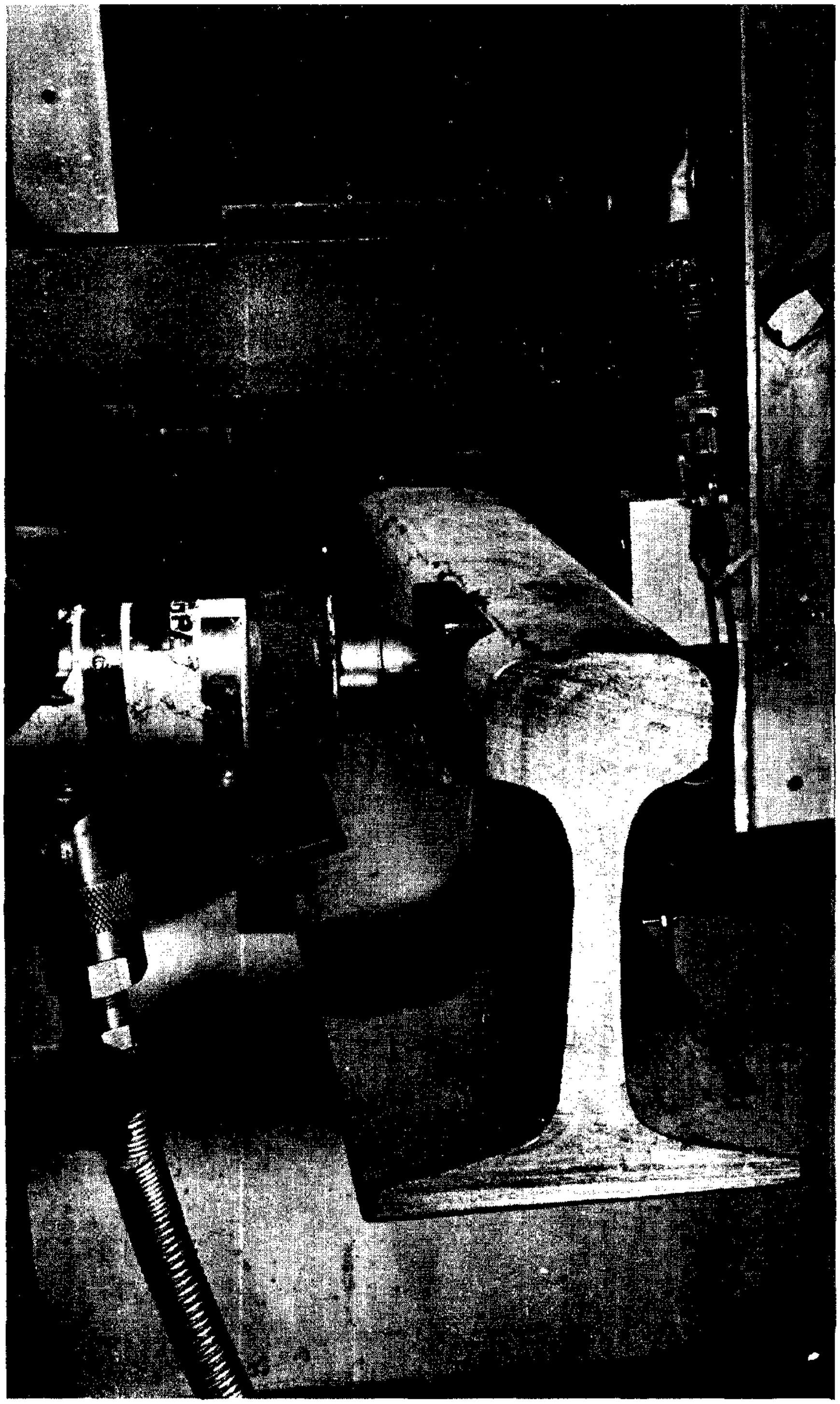


Figure 13. Test Set-Up for Fastener Resistance Test on Concrete Ties About the Vertical Axis, Showing Load Application Arrangement and Instrumentation.

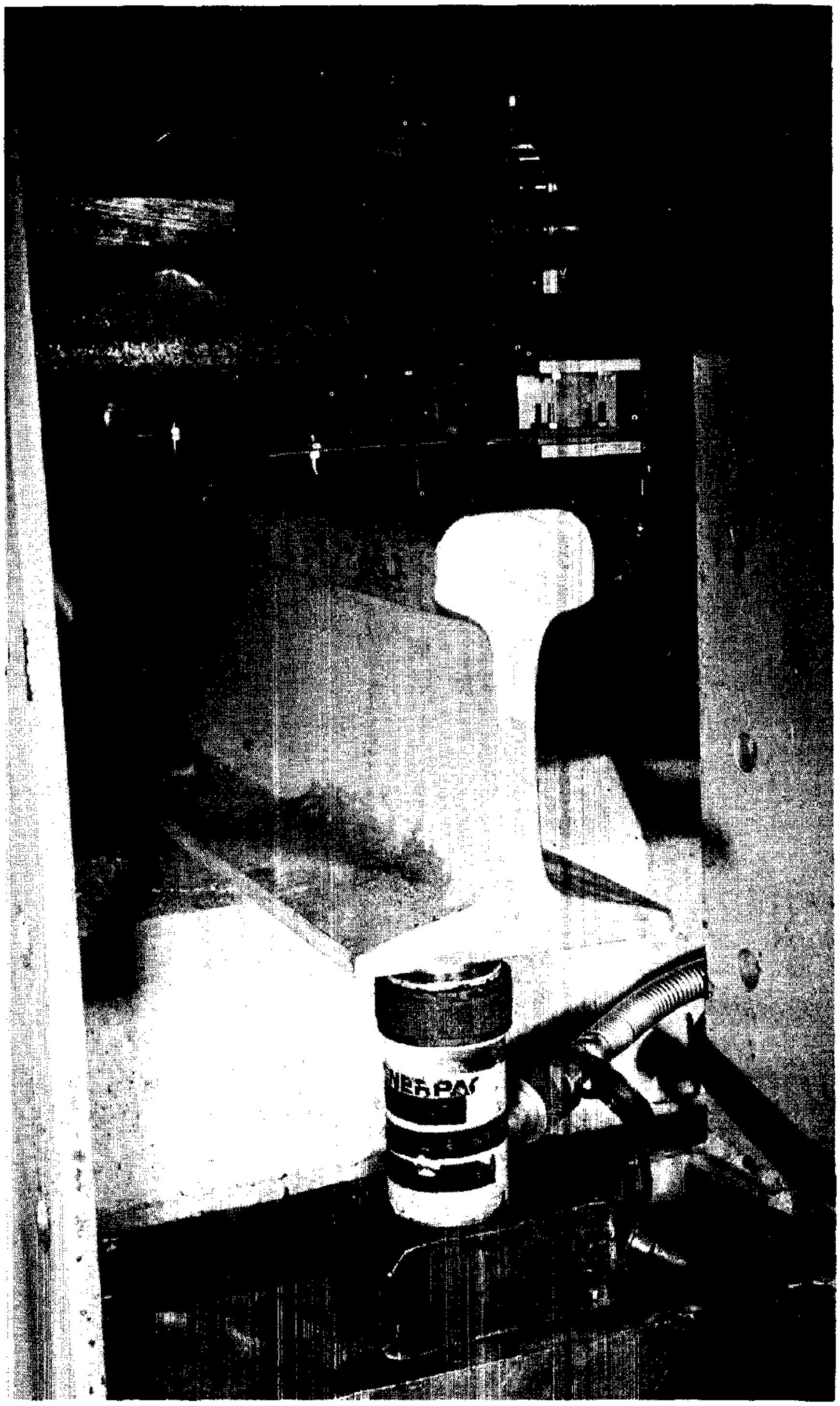


Figure 14. Test Set-Up for Fastener Resistance Test on Concrete Ties About the Lateral Axis, Showing Load Application Arrangement and Instrumentation.

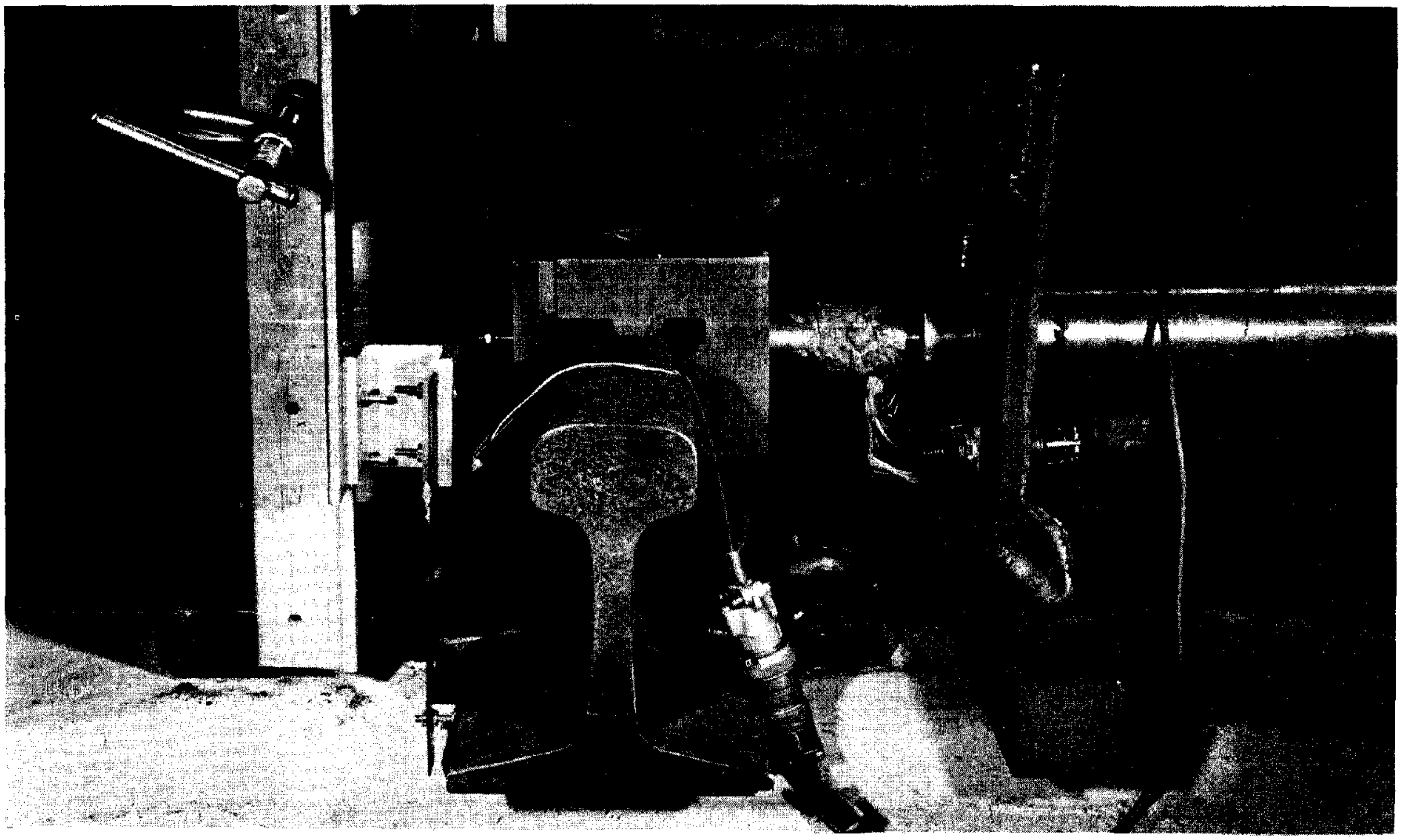


Figure 15. Test Set-Up for Fastener Resistance Test on Concrete Ties About the Longitudinal Axis, Showing Load Application Arrangement and Instrumentation.

with 136 RE rail section for the vertical, lateral and longitudinal axis respectively.

At the conclusion of each test, the fasteners and ties were inspected for damage. In all cases, the damage to both ties and fasteners was negligible.

Data was recorded during the test on both magnetic and paper tape and reduced in the manner described in Appendix A of Reference (1).

6.3 Results

The results of the fastener resistance tests are shown in tabular and graphical form. Tables 6, 7, and 8 give deflections, rotation and moments from a representative test for each of the axes, vertical, lateral and longitudinal, respectively. Figure 16, 17, and 18 are the plotted results of applied moment vs rail section rotation for the vertical, lateral and longitudinal axis, respectively. Each figure contains all three load cycles for the test of a given rail size.

In order to obtain a single value for the fastener torsional resistance, the torsional resistance for each of the three tests (each test was independently performed on a new tie with new fasteners) performed on the defined configurations was computed for rotations of 0.005 and 0.010 radians. The resulting six values were then averaged for each fastener configuration and are presented in Table 9 for the 115 RE rail section and Table 10 for the 136 RE rail section.

TABLE 6. FASTENER STIFFNESS TEST ABOUT VERTICAL AXIS
PANDROL
CONCRETE TIE
TEST NUMBER 3

LOAD (LB)	MOMENT (IN-LB)	DEFLECTION (IN) D1	D2	ROTATION 10E-2 (RAD)
0.00	0.0	0.0000	0.0001	0.0010
39.09	933.3	0.0001	0.0001	0.0019
71.02	1704.5	0.0001	0.0001	0.0019
131.62	3158.8	0.0003	0.0004	0.0067
131.62	3158.8	0.0003	0.0004	0.0067
167.45	4018.9	0.0005	0.0005	0.0095
194.82	4675.7	0.0009	0.0008	0.0162
229.35	5504.5	0.0059	0.0040	0.0943
268.45	6442.7	0.0144	0.0093	0.2257
274.96	6599.1	0.1603	0.1170	2.6403
329.04	7897.0	0.2236	0.1619	3.6698
359.67	8632.0	0.2437	0.1750	3.9855
386.38	9273.1	0.2540	0.1825	4.1548
470.43	11290.4	0.2713	0.1961	4.4485
493.89	11853.4	0.2794	0.2017	4.5787
0.65	15.6	0.2693	0.1934	4.4038

TABLE 7. FASTENER STIFFNESS TEST ABOUT LATERAL AXIS

TRUE TEMPER CLIPLOCK
CONCRETE TIE
TEST NUMBER 2

LOAD (LB)	MOMENT (IN-LB)	DEFLECTION (IN)		ROTATION 10E-2 (RAD)
		D1	D2	
121.19	2908.6	0.0030	0.0036	0.0629
227.40	5457.6	0.0061	0.0099	0.1524
336.86	8084.7	0.0137	0.0191	0.3124
452.19	10852.6	0.0224	0.0305	0.5038
656.78	15762.8	0.0433	0.0604	0.9876
899.17	21530.0	0.0667	0.1025	1.6113
1114.19	26740.4	0.0855	0.1356	2.1054
1328.55	31885.2	0.1043	0.1694	2.6061
1557.90	37389.7	0.1236	0.2040	3.1190
1770.32	42487.6	0.1443	0.2432	3.6888
2000.97	48023.3	0.1637	0.2763	4.1880
0.65	15.6	0.0203	0.0193	0.3867

TABLE 8. FASTENER STIFFNESS TEST ABOUT LONGITUDINAL AXIS
PANDROL
CONCRETE TIE
TEST NUMBER 1

LOAD (LB)	MOMENT (IN-LB)	DEFLECTION (IN)			ROTATION 10E-2 (RAD)
		D1	D2	D3	
917.08	5845.4	0.0006	0.0196	0.0016	0.2902
1122.96	7158.9	0.0022	0.0389	0.0011	0.5843
1302.63	8304.3	0.0032	0.0585	0.0006	0.8878
1564.66	9974.7	0.0032	0.0788	0.0010	1.2031
1699.41	10833.8	0.0034	0.0974	0.0021	1.4846
1819.20	11597.4	0.0037	0.1170	0.0038	1.7763
1920.26	12241.7	0.0038	0.1365	0.0048	2.0734
2010.10	12814.4	0.0036	0.1558	0.0057	2.3705
2099.94	13387.1	0.0035	0.1752	0.0069	2.6660
2178.54	13888.2	0.0034	0.1946	0.0076	2.9654
2275.87	14508.6	0.0032	0.2141	0.0084	3.2663
2354.47	15009.8	0.0023	0.2335	0.0090	3.5687
2425.59	15463.2	0.0027	0.2529	0.0096	3.8687

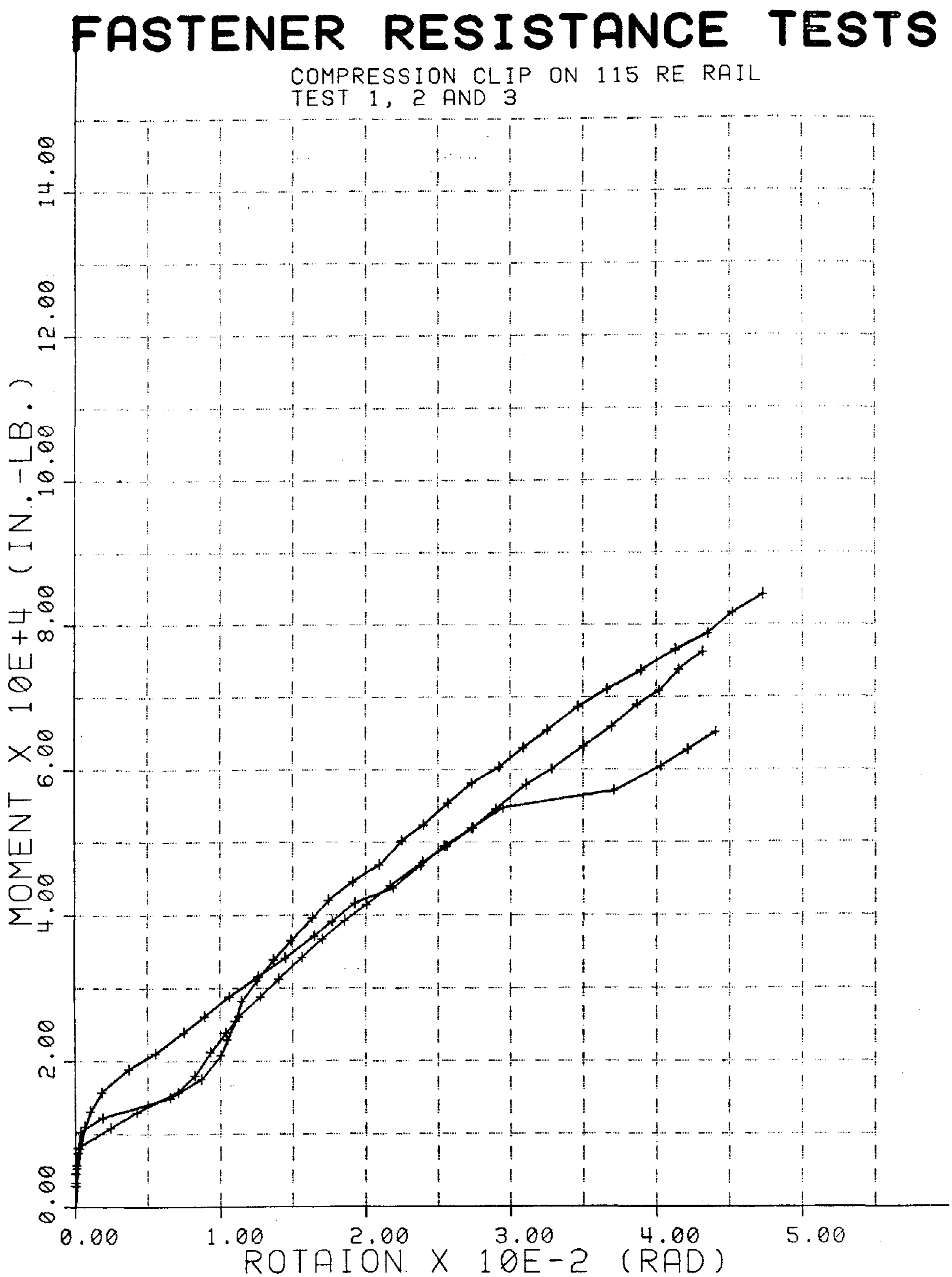


FIGURE 16. ROTATION ANGLE VS APPLIED MOMENT FOR THREE FASTENER RESISTANCE TESTS ABOUT THE VERTICAL AXIS.

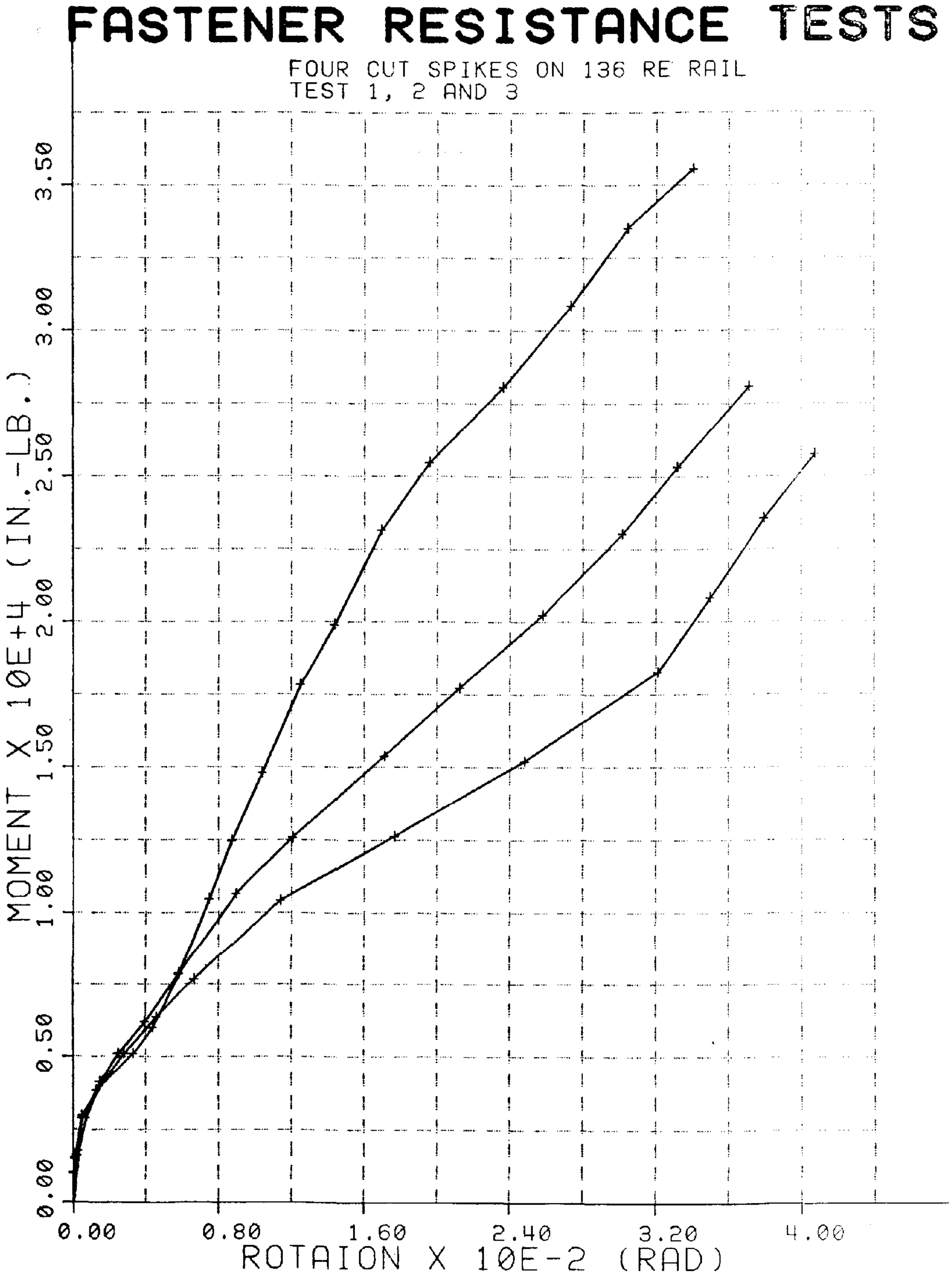


FIGURE 17. ROTATION ANGLE VS APPLIED MOMENT FOR THREE FASTENER RESISTANCE TESTS ABOUT THE LATERAL AXIS.

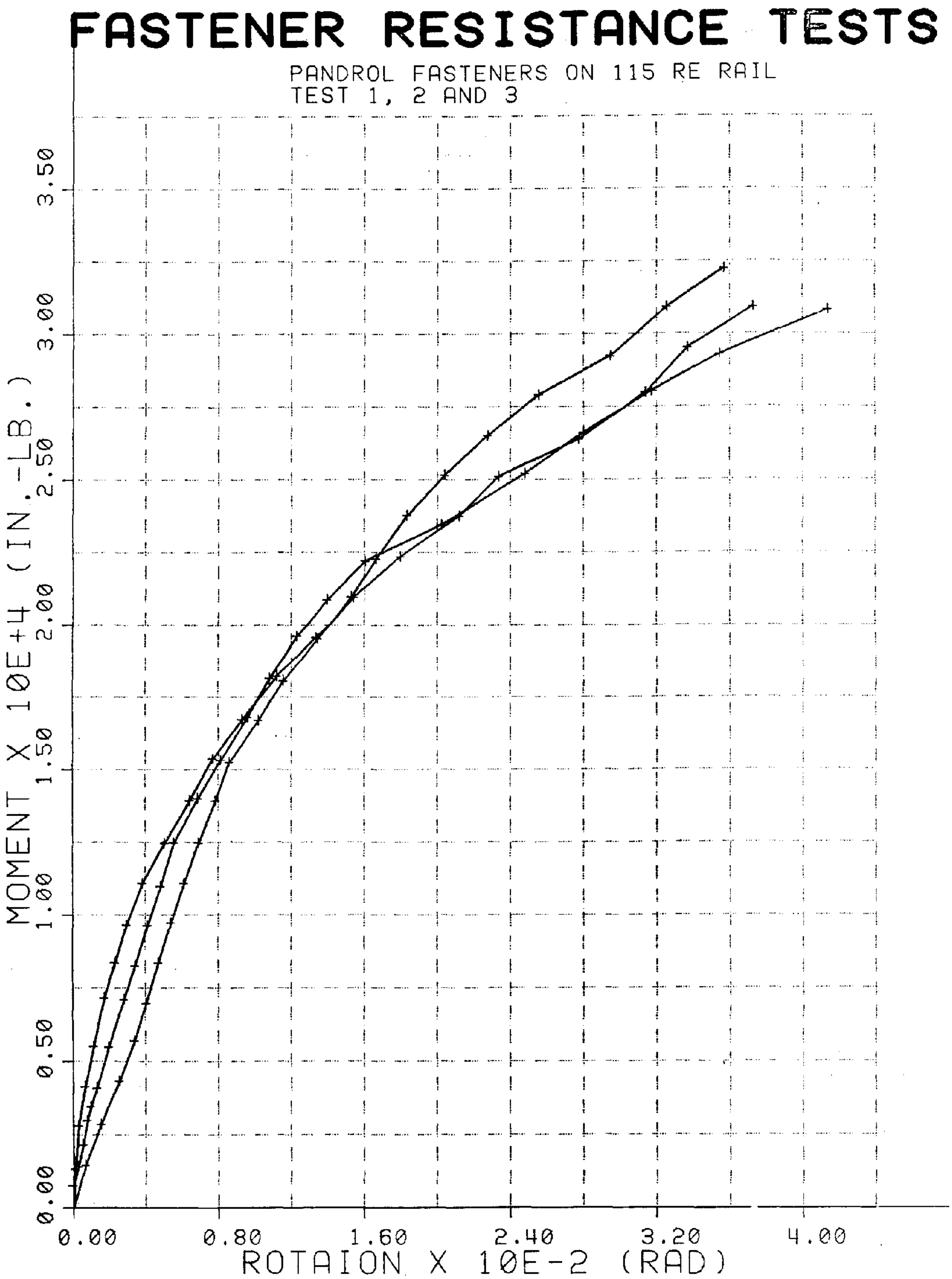


FIGURE 18. ROTATION ANGLE VS APPLIED MOMENT FOR THREE FASTENER RESISTANCE TESTS ABOUT THE LONGITUDINAL AXIS.

TABLE 9. FASTENER ROTATIONAL RESISTANCE TEST RESULTS FOR 115 RE RAIL SECTION ON WOOD TIES

	ROTATIONAL STIFFNESS 10**6(LB.-IN/RADIAN)		
TYPE OF FASTENER	VERTICAL AXIS	LATERAL AXIS	LONGITUDINAL AXIS
2 CUT SPIKES	0.92*	1.68	1.49
4 CUT SPIKES	3.32*	1.64	3.09
PANDROL	3.52*	0.73	1.66
SCREW SPIKE	1.27	1.89	2.60
COMPRESSION CLIP	2.79	0.94	1.99

* Note results are taken from Volume I (1) of this report.

TABLE 10. FASTENER ROTATIONAL RESISTANCE TEST RESULTS FOR 136 RE RAIL SECTION ON WOOD TIES AND CONCRETE TIES.

	ROTATIONAL STIFFNESS 10**6(LB.-IN/RADIAN)		
TYPE OF FASTENER	VERTICAL AXIS	LATERAL AXIS	LONGITUDINAL AXIS
2 CUT SPIKES	1.47*	1.41	1.62
4 CUT SPIKES	3.26*	1.27	1.96
PANDROL	4.95*	1.29	2.16
SCREW SPIKE	1.34	2.47	1.65
COMPRESSION CLIP	1.84	1.42	1.54
	CONCRETE TIE		
PANDROL	1.10	**	1.11
RAIL CLIP(RT-7)	2.26	1.49	1.83

* Note results are taken from Volume I (1) of this report.

** Questionable data.

7.0 REFERENCES

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15. Supplementary Notes

16. Abstract

This report describes the test procedures and the results of the tests on the physical properties of rail, concrete ties, jointbars and fasteners. The properties obtained are the torsional rigidity of rail, bending rigidity of concrete ties, bending stiffness of jointbars and fastener resistance to rotation about the vertical, lateral and longitudinal axis. The components tests were run on two rail sections, 115 RE and 136 RE, on five different concrete ties, on 136 RE rail joint bars, and on five fasteners configurations on the two different rails on wood ties and two configurations on the 115 RE rail on concrete ties.

The tests were conducted at the Association of American Railroads (AAR) Track Laboratory in Chicago, Illinois.

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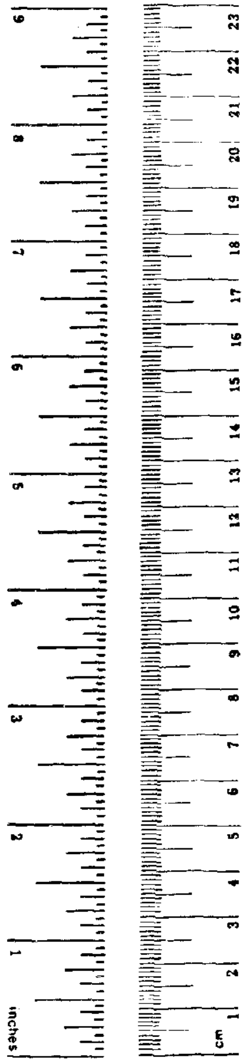
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F