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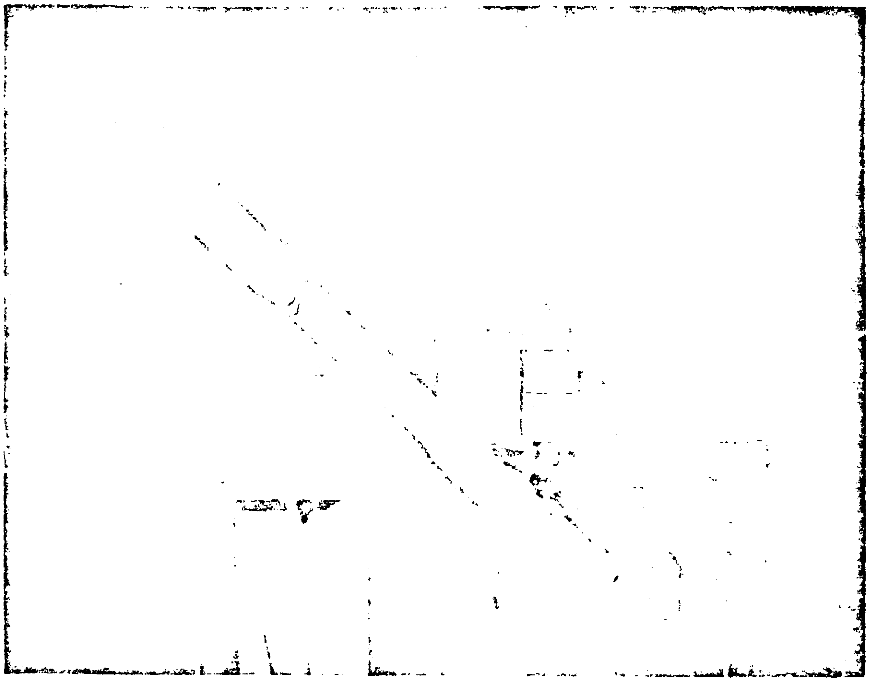

CAPABILITY OF FASTENERS TO RESIST RAIL OVERTURNING

NOVEMBER 1967

ENGINEERING RESEARCH DIVISION
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Chicago, Illinois
60616

ASSOCIATION OF AMERICAN RAILROADS

RESEARCH DEPARTMENT

Engineering Research Division

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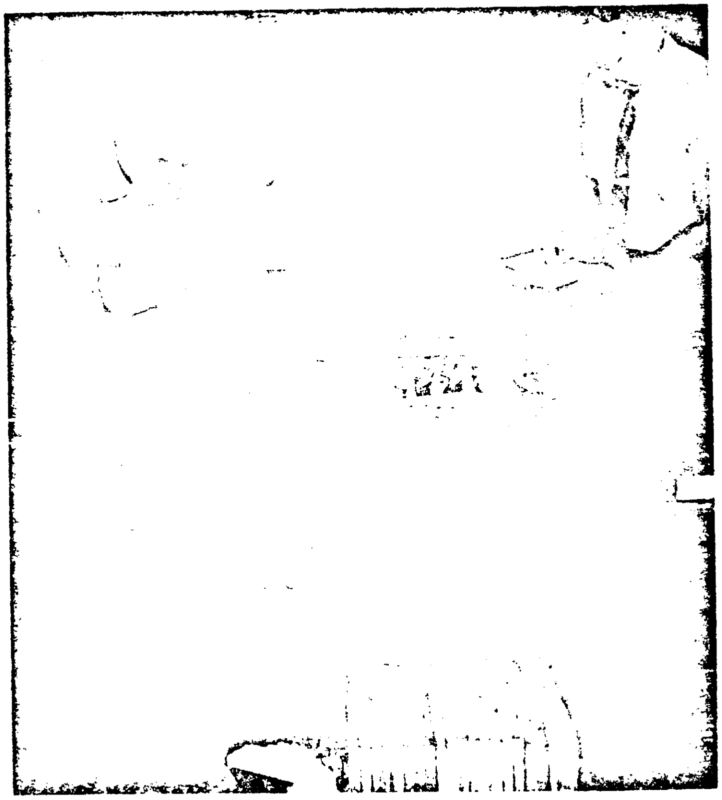

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NOVEMBER 1967

RAIL OVERTURNING INVESTIGATION ON WOOD AND CONCRETE TIES

FOREWORD

The increased use of longer and heavier cars has created many problems and within recent years some railroads have experienced wheel lifting, rail climbing, derailments, loss of gage and rail overturning on curves. Considerable research has been done by the AAR Research Center to determine the cause or causes of this trouble and several ER reports have been issued on the subject. In general, the test data indicate that the wheels of the car will exert lateral forces as large as 30, 000 lb on the rail under certain operating conditions, but such forces are usually associated with high vertical forces on the rail. In addition, only about 50 percent of this load is carried by the tie directly under the wheel with the two adjacent ties carrying the other 50 percent of the wheel load.

The purpose of the investigation reported herein was to determine the overturning resistance of the rail fastened to either wood or prestressed concrete ties when subjected to various loading conditions. No effort was made to include the torsional resistance of the rail which would increase the overturning resistance by a considerable amount so the data obtained must be considered as conservative.

The investigation was conducted in the engineering laboratory of the Research Center as part of the research activity of the Research Department of which W. M. Keller is vice-president and G. M. Magee is director of engineering research. Funds for the investigation were provided by the AAR.

The investigation was under the direction of E. J. Ruble, executive research engineer, assisted by F. P. Drew, research engineer structures and K. W. Schoeneberg, research engineer track. Mr. I. A. Eaton, laboratory engineer, was in charge of the laboratory testing.

TEST PROCEDURE

The procedure used in testing the rail on the wood ties was accomplished by fastening a short piece of 136 lb rail and tie plate to a new treated oak tie by four spikes in pre-bored holes; two of the spikes were placed in the line position against the edges of the rail base and two were placed in the outer holes of the tie plate to hold the tie plate to the tie, as shown on Fig. 1. The rail on the prestressed concrete tie was fastened by two bolts and two AREA Specification clips with a 3/16 in polyethylene plastic pad between the rail and concrete.

The rail and tie assembly was placed on the testing floor as shown on Figs. 1 and 2. The tie was positioned under the hydraulic Amsler jack so that the load was applied vertically to the head of the rail. The tie was installed at the proper angle or slope to secure the desired lateral and vertical components of load on the rail.

The lateral movements of the rail head and base produced by the lateral component of the load on the rail were determined by dial gages mounted as shown on Figs. 1 and 2. The one dial on the rail base shown on the pictures proved unsatisfactory due to the angle of the plunger rod and all subsequent tests were conducted with two dial gages on the rail; one on each side of the tie. The average of the two dial gage readings was used as the lateral movement of the rail.

In conducting the tests, the rail was loaded by small increments of load, taking dial gage readings for each load increment, until failure developed.

RESULTS

The relation between the load on rail and the lateral movement of the rail for various positions of the ties are tabulated on Tables 1 to 4, incl. for both the wood and prestressed concrete ties. For example, Table 1 shows the data for the tie in the vertical position so that the load on the rail has a lateral component only without any vertical component. For this position of the tie, the rail on the wood tie turned over under a lateral load of 6400 lb. The dial gages were removed after taking the readings for the 5500 lb load. Under a lateral load of 5500 lb the head of the rail moved 0.210 in while the base moved 0.031 in.

The rail fastened to the prestressed concrete tie failed under a lateral load of 10,850 lb with the head of the rail moving 0.325 in at the instant of failure. Time did not permit the reading of the dial gage on the base of rail, but a movement of 0.028 in was recorded under a lateral load of 10,500 lb. Failure resulted from a chipping of the concrete bearing area at the recess on the field side.

The data obtained with the tie on a slope of 2 to 1 or an angle of 63°-30' between the tie and the test floor, are shown on Table 2. It can be seen that the rail on the wood tie turned over under a rail load of 5100 lb. The rail load of 5100 lb produced a lateral component on the rail of 4600 lb and a vertical component of 2300 lb. Failure was caused by the spike on the gage side pulling out. It can be seen from Table 2 that the rail on the prestressed concrete tie carried a total rail load of 22,950 lb which produced a lateral component of 20,500 lb on the rail and a vertical component of 10,200 lb. The head of the rail moved laterally 0.755 in under a rail load of 22,000 lb while the rail base moved 0.220 in. Overturning of the rail resulted from the stainless steel anchor on the gage side pulling out but there was some slight chipping of the concrete bearing area at the recess on the field side.

The data obtained with the wood and prestressed concrete ties on a slope of 1 to 1 are shown on Table 3. The rail on the wood tie carried a total rail load of 14,000 lb which produced a lateral and vertical component of 9900 lb each. The head of the rail moved laterally 0.270 in and failure resulted from the spike pulling out on the gage side. The rail on the prestressed concrete tie carried a total rail load of 25,700 lb which produced a lateral and vertical component of 18,170 lb. The overturning of the rail resulted from a tension failure in the concrete on a plane even with the bottom of the stainless steel anchor on the gage side. The rail load for this prestressed concrete tie was greater than that for the wood tie even though the tie used for this particular test did not meet the requirements of the tentative specification of AREA Committee 3 for prestressed concrete ties and fastenings as the bottom of the stainless steel insert was only 1 3/4 in from the top of the tie instead of the specified 2 3/4 in and no vertical stirrups or ties were used in the rail seat area. A greater rail load can be expected for the prestressed concrete ties when made in conformance with the specifications.

The data with the wood tie on a slope of 1 to 2 are shown on Table 4. The load on the rail was increased by increments to 40,000 lb and since there was no indication of rail lifting or impending failure, the tests were discontinued. The data with the rail fastened to the prestressed concrete ties under two conditions of bolt tension are shown on Table 4. The first tests were conducted with the bolts tightened to a torque of 150 ft lb as requied in the tentative specification. The load was increased by increments and failure resulted under a load of 60,000 lb when the field side shoulder on the recess failed by a chipping of the concrete. The second tests were conducted with the bolts tightened to a torque of 75 ft lb as field experience has shown that some bolt tension will be lost under traffic. The load was increased by increments as shown on Table 4 to 92,500 lb, the capacity of the hydraulic jack, without failure of the shoulder on the recess.

The relation between the lateral load on the rail and the lateral deflection of the rail head and base, as tabulated in Tables 1 to 4 incl., is shown on Figs. 3 to 10 incl. It can be seen that the rail on the prestressed concrete ties carried an appreciably greater lateral load than the rail on the wood ties. The lateral deflection of the rail head and base for the rails on the prestressed concrete ties was considerably greater than that for the rails on the wood ties at failure, however, for the same lateral load on the rail, the head and base deflections were lower for the prestressed concrete ties.

SUMMARY

A summary of all test data as shown in Tables 1 to 4 incl. and Figs. 3 to 10 incl. are shown on Fig. 11 for the two types of fastenings and the four different angles or slopes of the ties. The lateral component of the rail load producing rail overturning or failure is plotted as the ordinate and the ratio of the vertical component to the lateral component of the rail load is plotted as the abscissa. It is quite evident that the rail on the prestressed concrete ties is capable of carrying considerably more lateral load than the rail fastened to wood ties with spikes.

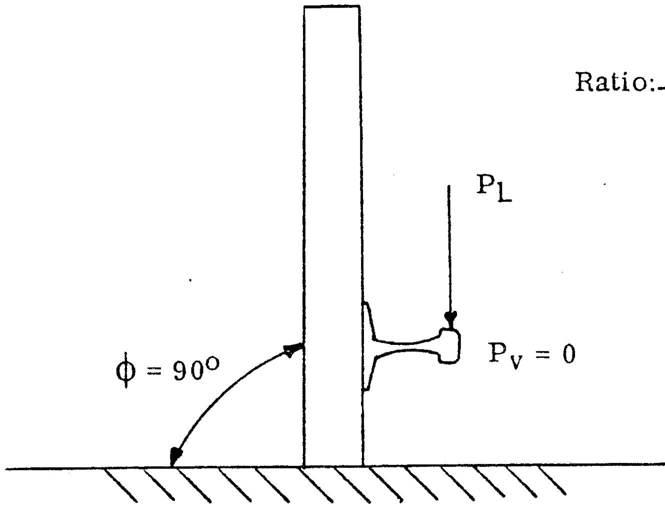
An analytical study conducted at the Research Center indicate a definite relation between the wheel lifting off the rail, wheel climbing the rail and the lateral and vertical loads on the rail. For example, when the lateral component of the load on the rail is 82 percent of the vertical load or when P_V/P_L is equal to 1.22, there is impending wheel lift and this ratio is shown by the vertical dashed line. When the lateral component of the load on the rail is 1.29 times the vertical load component or when P_V/P_L is equal to 0.78, there is impending wheel climbing of the rail and this ratio is shown by the vertical dashed line.

The results of the analytical study shown on Fig. 11 indicate that all values of P_V/P_L smaller than 0.78 have no significance as the wheel will climb the rail and thus relieve the lateral load component on the rail. As previously mentioned, lateral wheel loads as large as 30,000 lb have been recorded and for this condition, the analytical study indicate the wheel will not climb the rail until the vertical component of the rail load is 23,400 lb or lower.

CONCLUSION

The method of fastening the rail to the prestressed concrete ties, as recommended in the Preliminary Specification for Design, Materials, Construction and Inspection of Prestressed Concrete Ties, is satisfactory for the imposed lateral forces.

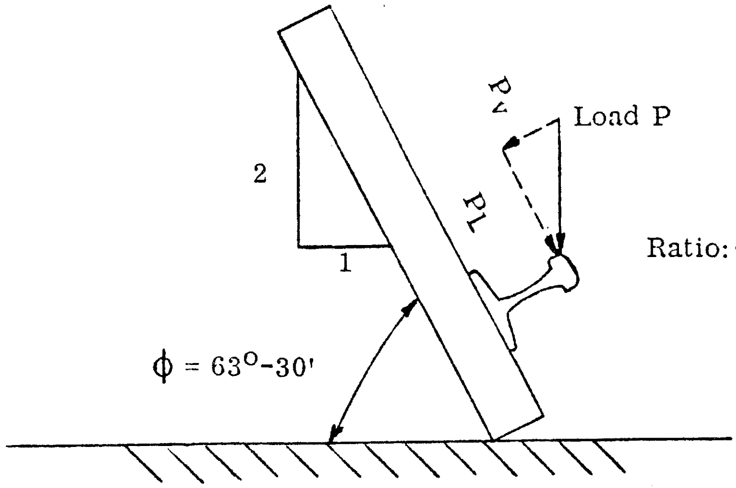
TABLE 1
RAIL OVERTURNING INVESTIGATION
Wood and Concrete Ties



Type of Tie	Load P Lbs.	P_L Lbs.	P_V Lbs.	Rail Movement-In.	
				Head	Base
Wood	0	0	0	0	0
	2000	2000	0	0.030	0.020
	4000	4000	0	0.122	0.023
	5500[2]	5500	0	0.210	0.031
	6400	6400	0	-	-
Concrete (AREA Comm. 3 Spec.)	0	0	0	0	0
	1550	1550	0	0.020	0
	2360	2360	0	0.060	0.003
	3110	3110	0	0.100	0.006
	3840	3840	0	0.140	0.009
	4600	4600	0	0.180	0.013
	5450	5450	0	0.220	0.015
	7940	7940	0	0.260	0.019
	9710	9710	0	0.300	0.024
	10500	10500	0	0.320	0.028
	10850[1]	10850	0	0.325	-

(1) Failure by chipping of concrete at recess.
(2) Dial gages removed.

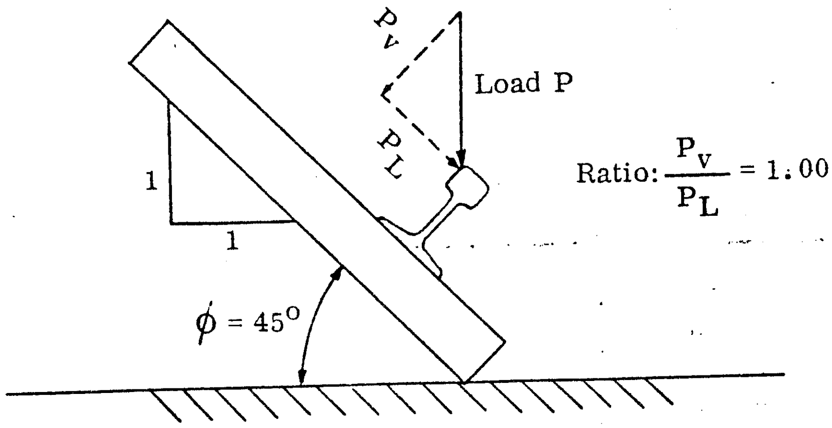
TABLE 2
RAIL OVERTURNING INVESTIGATION
Wood and Concrete Ties



Type of Tie	Load P Lbs.	P_L Lbs.	P_V Lbs.	Rail Movement-In.	
				Head	Base
Wood (Oak)	0	0	0	0	0
	2000	1800	900	0.024	0.007
	4000(1)	3600	1800	0.068	0.018
	5100(2)	4600	2300		
Concrete (AREA Comm. 3 Spec.)	2000	1800	900	0.008	0
	4000	3600	1800	0.021	0.001
	6000	5400	2700	0.092	0.005
	8000(3)	7200	3600	0.285	0.016
	10000(4)	8900	4500	0.428	0.126
	12000	10800	5400	0.452	0.131
	14000	12500	6200	0.480	0.138
	16000	14400	7100	0.515	0.150
	18000	16100	8000	0.566	0.166
	20000	17800	8900	0.618	0.185
	22000	19800	9900	0.755	0.220
	22950(5)	20500	10200	-	-

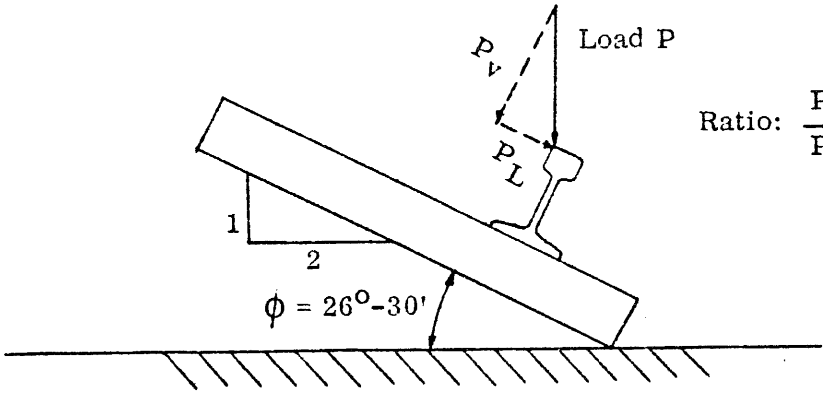
(1) Rail lifting.
(2) Complete failure. Spike on gage side pulled out.
(3) Rail lifting.
(4) Slight chipping of concrete on field side.
(5) Complete failure. Stainless steel anchor on gage side pulled out.

TABLE 3
RAIL OVERTURNING INVESTIGATION
Wood and Concrete Ties



Type of Tie	Load P Lbs.	P_L Lbs.	P_v Lbs.	Rail Movement-In. Head	Base
Wood (Oak)	0	0	0	0	0
	2000	1410	1410	0.015	0.001
	4000	2820	2820	0.040	0.003
	6000	4240	4240	0.064	0.007
	8000	5660	5660	0.088	0.012
	10000(1)	7070	7070	0.120	0.020
	12000	8480	8480	0.180	0.031
	14000(2)	9900	9900	0.270	-
Concrete Not AREA Comm. 3 Spec.	0	0	0	0	0
	2000	1410	1410	0.004	0.001
	4000	2820	2820	0.011	0.002
	6000	4240	4240	0.025	0.004
	8000	5660	5660	-	0.008
	10000(3)	7070	7070	0.120	0.015
	12000	8480	8480	0.180	0.021
	14000(4)	9900	9900	0.250	0.031
	16000	11300	11300	0.555	0.080
	18000	12700	12700	0.588	0.090
	20000	14140	14140	0.620	0.103
	22000	15600	15600	0.665	0.173
	24000	17000	17000	0.880	0.240
	25700(5)	18170	18170	0.900	-

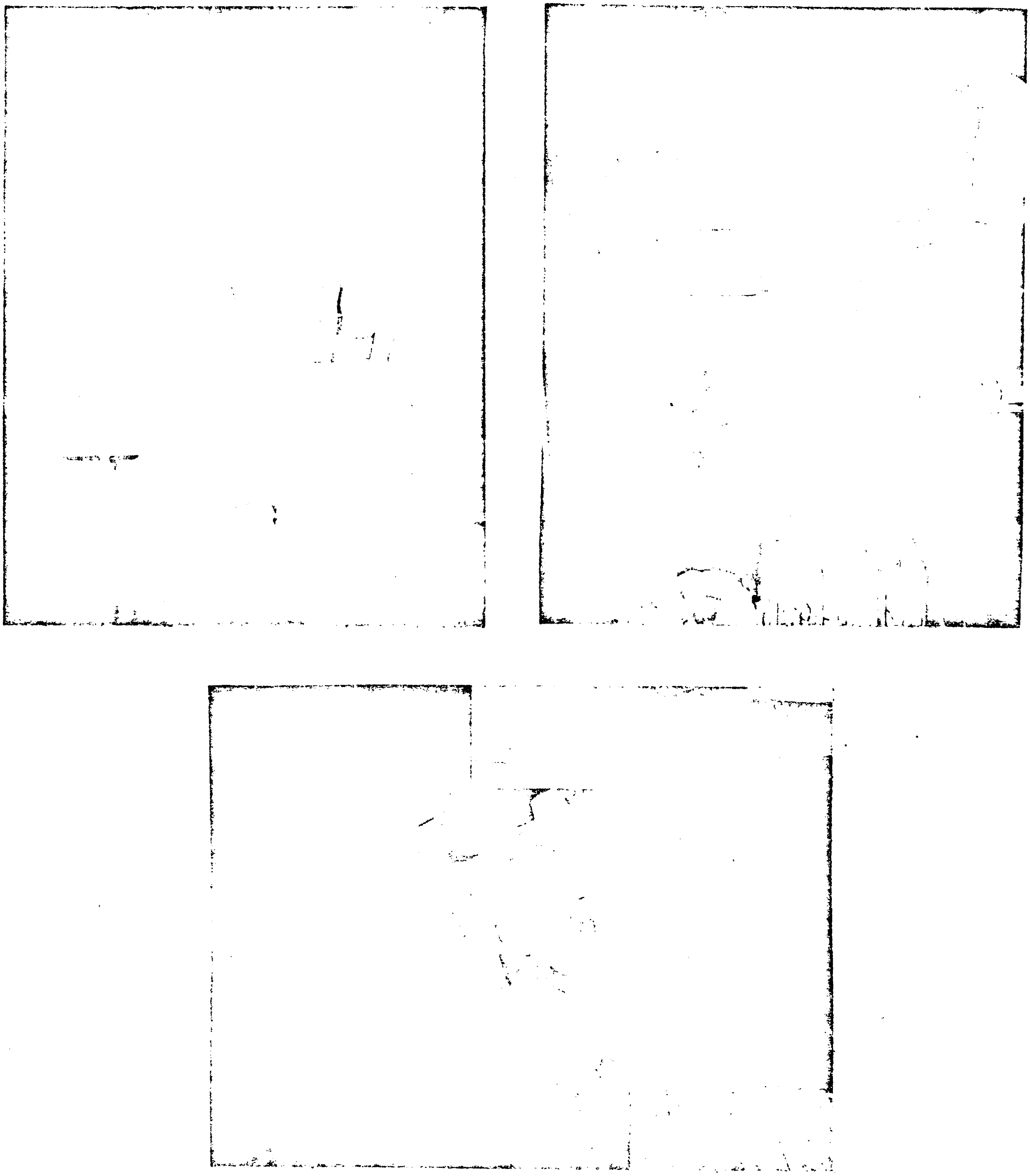
(1) Rail lifting.
(2) Complete failure. Spike on gage side pulled out.
(3) Rail lifting.
(4) Slight chipping of concrete on field side.
(5) Complete failure. Tension failure of concrete on a plane with bottom of anchor.



Type of Tie	Load P Lbs	P_L Lbs	P_v Lbs	Rail Movement-In.	
				Head	Base
Wood	0	0	0	0	0
	4,000	1,800	3,600	0.032	0.020
	8,000	3,600	7,200	0.059	0.034
	12,000	5,400	10,800	0.076	0.045
	16,000	7,100	14,400	0.092	0.055
	20,000	8,900	17,800	0.110	0.060
	24,000	10,700	21,400	0.128	0.080
	28,000	12,400	24,900	0.147	0.094
	32,000	14,300	28,600	0.167	0.109
	36,000	16,000	32,000	0.191	0.127
	40,000(1)	17,800	35,600	0.209	0.139
Concrete Not AREA Com. 3 Spec. 150 ft lb torque on bolts as specified.	0	0	0	0	0
	8,000	3,600	7,200	0.007	0.001
	16,000	7,100	14,400	0.015	0.001
	24,000	10,700	21,400	0.024	0.003
	32,000	14,300	28,600	0.034	0.005
	40,000	17,800	35,600	0.044	0.010
	48,000	21,400	42,800	0.054	0.014
	56,000(2)	24,800	49,800	0.069	0.024
	60,000(3)	26,700	53,400	-	-
Concrete Not AREA Com. 3 Spec. 75 ft lb torque on bolts.	0	0	0	0	0
	8,000	3,600	7,200	0.010	0
	16,000	7,100	14,400	0.016	0.003
	24,000(4)	10,700	21,400	0.032	0.015
	32,000	14,300	28,600	0.058	0.033
	40,000	17,800	35,600	0.068	0.040
	48,000	21,400	42,800	0.081	0.046
	56,000	24,800	49,800	0.094	0.053
	64,000	28,600	57,200	0.111	0.064
	72,000	32,000	64,000	0.124	0.071
	92,500(5)	41,100	82,200	-	-

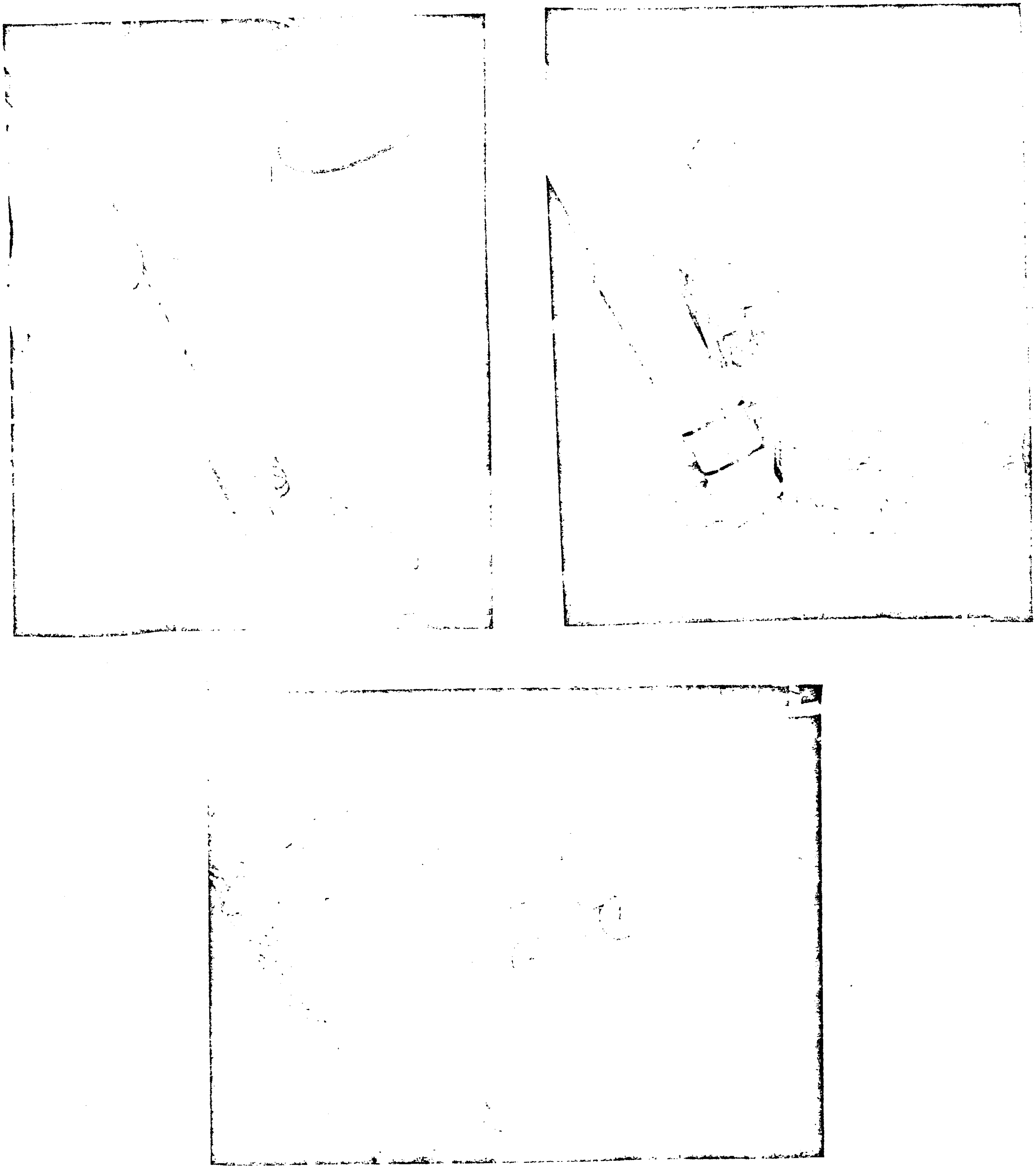
(1) No failure and no lifting of rail.
(2) Slight chipping of concrete on field side.
(3) Failure by chipping of concrete on field side.
(4) Slight chipping of concrete on field side.
(5) No failure. Maximum capacity of jack.

FIG. 1
RAIL OVERTURNING INVESTIGATION



General view of wood tie and fastenings before testing.

FIG. 2
RAIL OVERTURNING INVESTIGATION



General view of prestressed concrete tie and fastenings after failure of anchor.

DEFLECTION IN RAIL HEAD

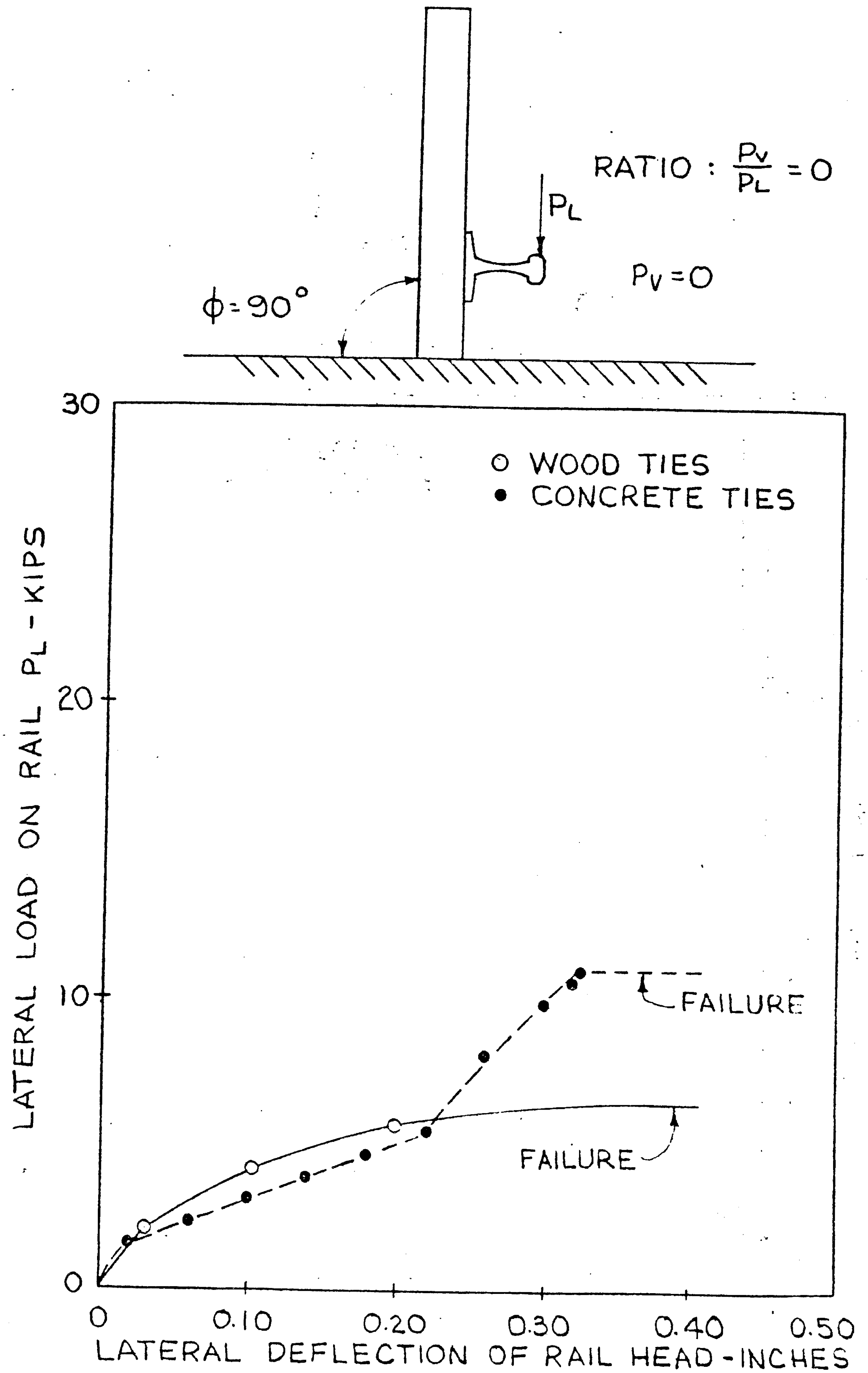


FIG. 4
RAIL OVERTURNING INVESTIGATION
DEFLECTION OF RAIL BASE

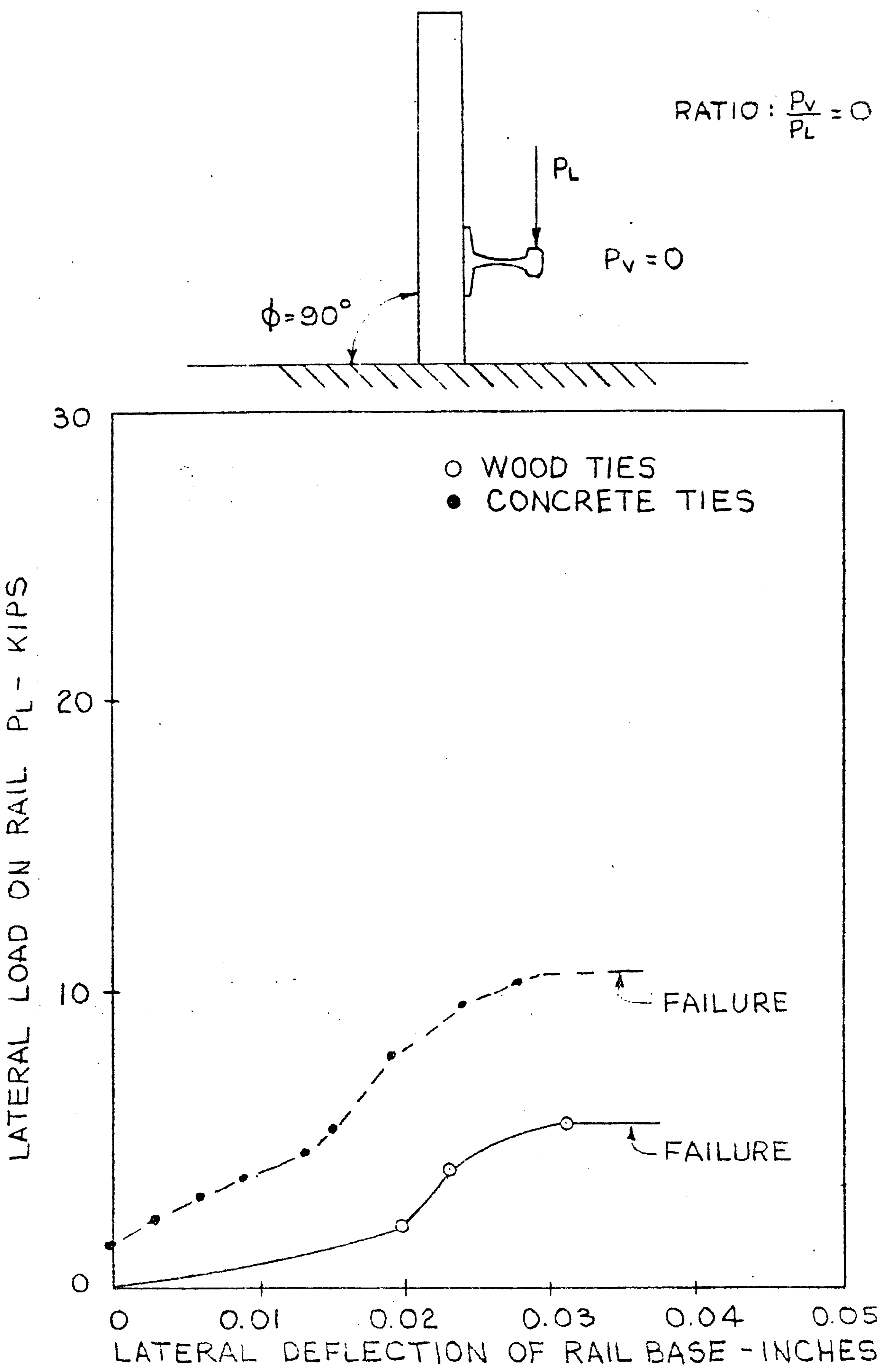


FIG. 5
RAIL OVERTURNING INVESTIGATION
DEFLECTION OF RAIL HEAD

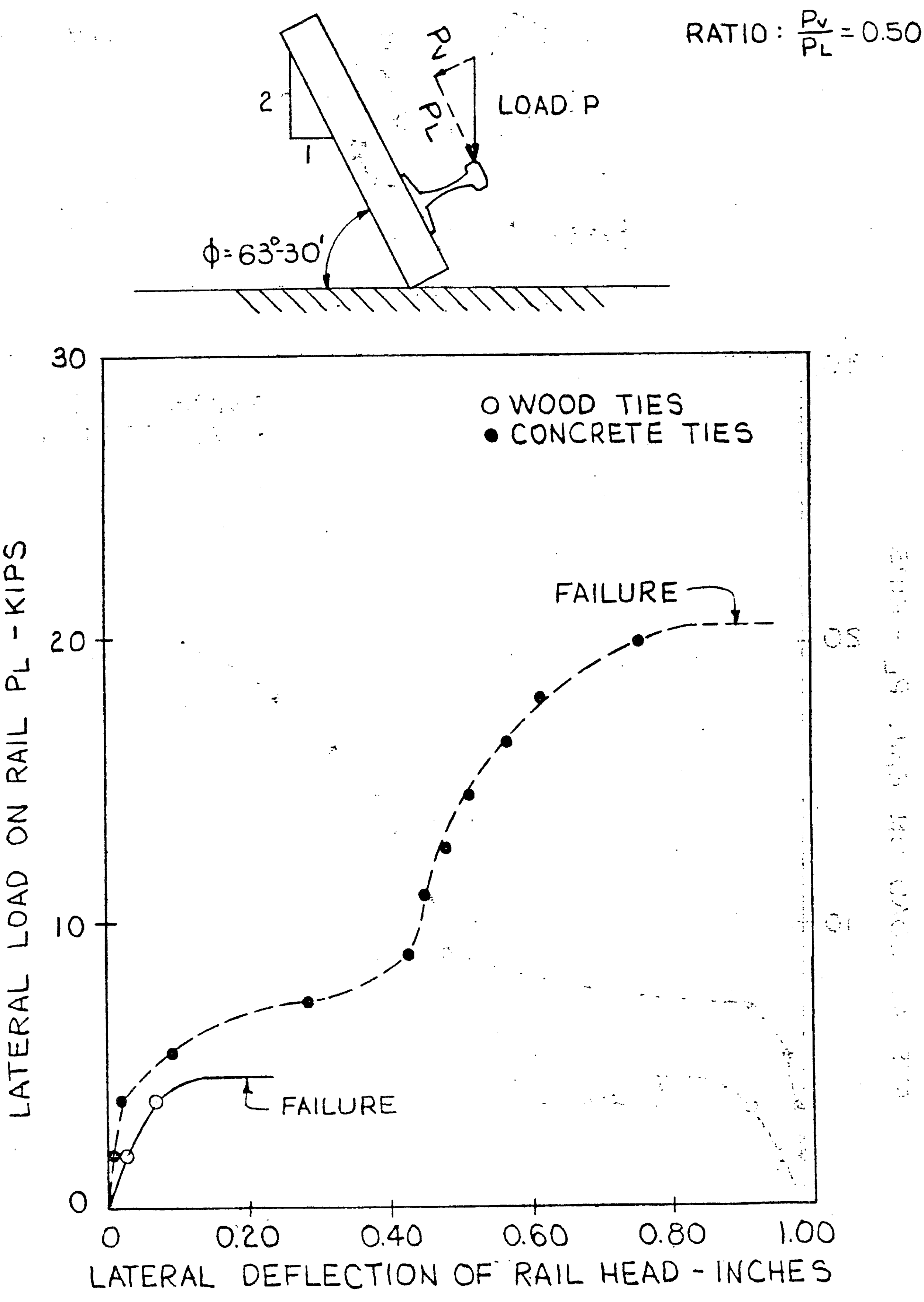
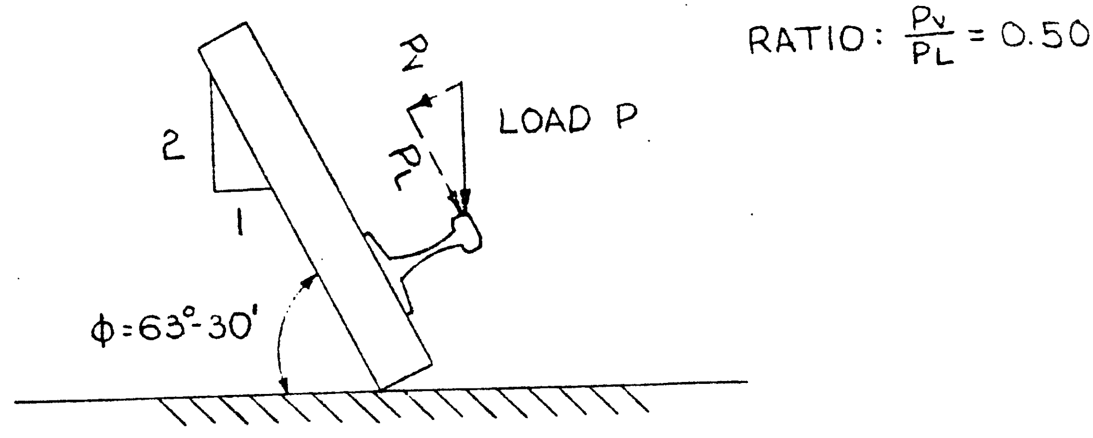


FIG. 6
RAIL OVERTURNING INVESTIGATION
DEFLECTION OF RAIL BASE



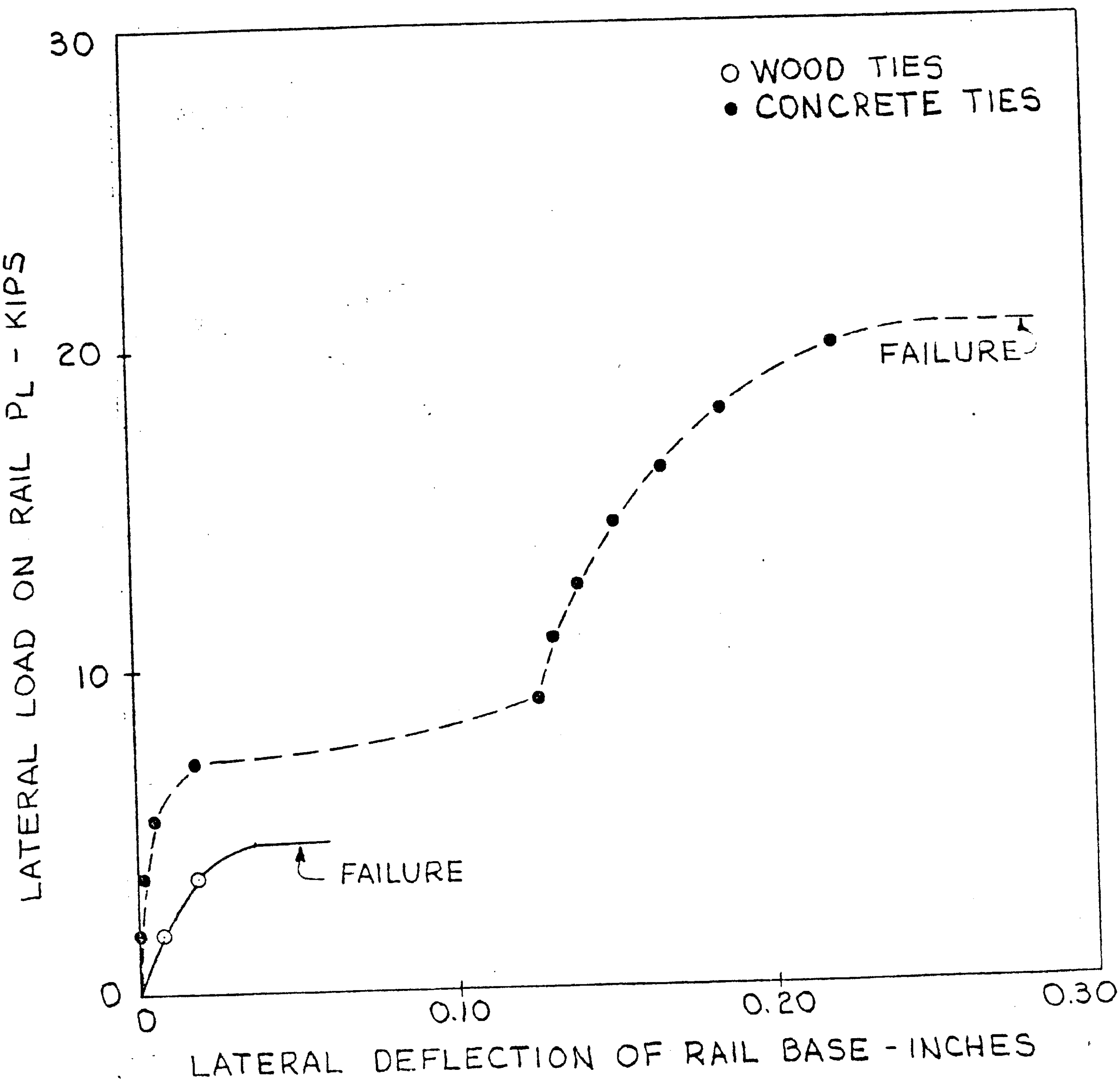


FIG. 7
RAIL OVERTURNING INVESTIGATION
DEFLECTION OF RAIL HEAD

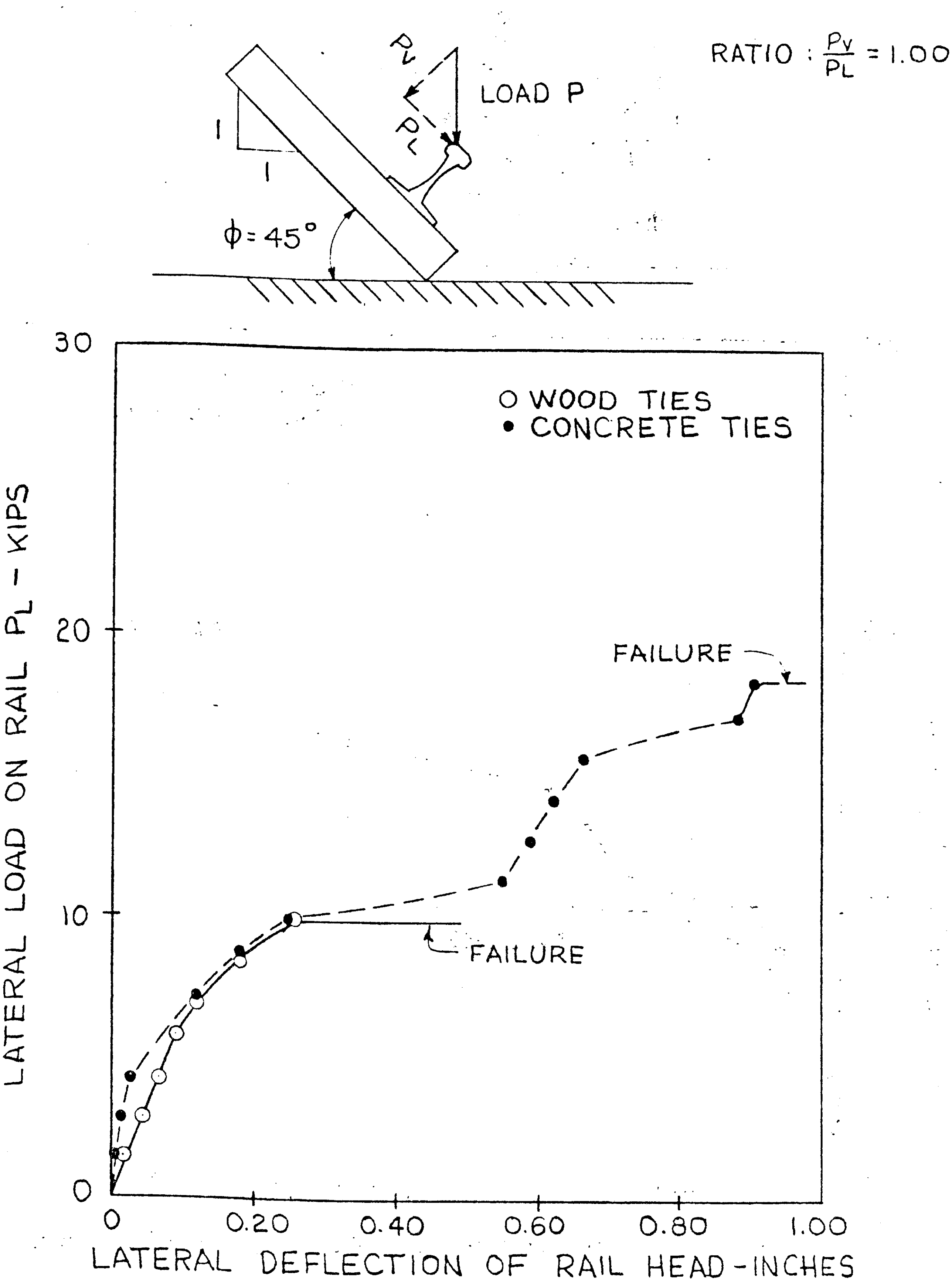


FIG. 8
RAIL OVERTURNING INVESTIGATION
DEFLECTION OF RAIL BASE

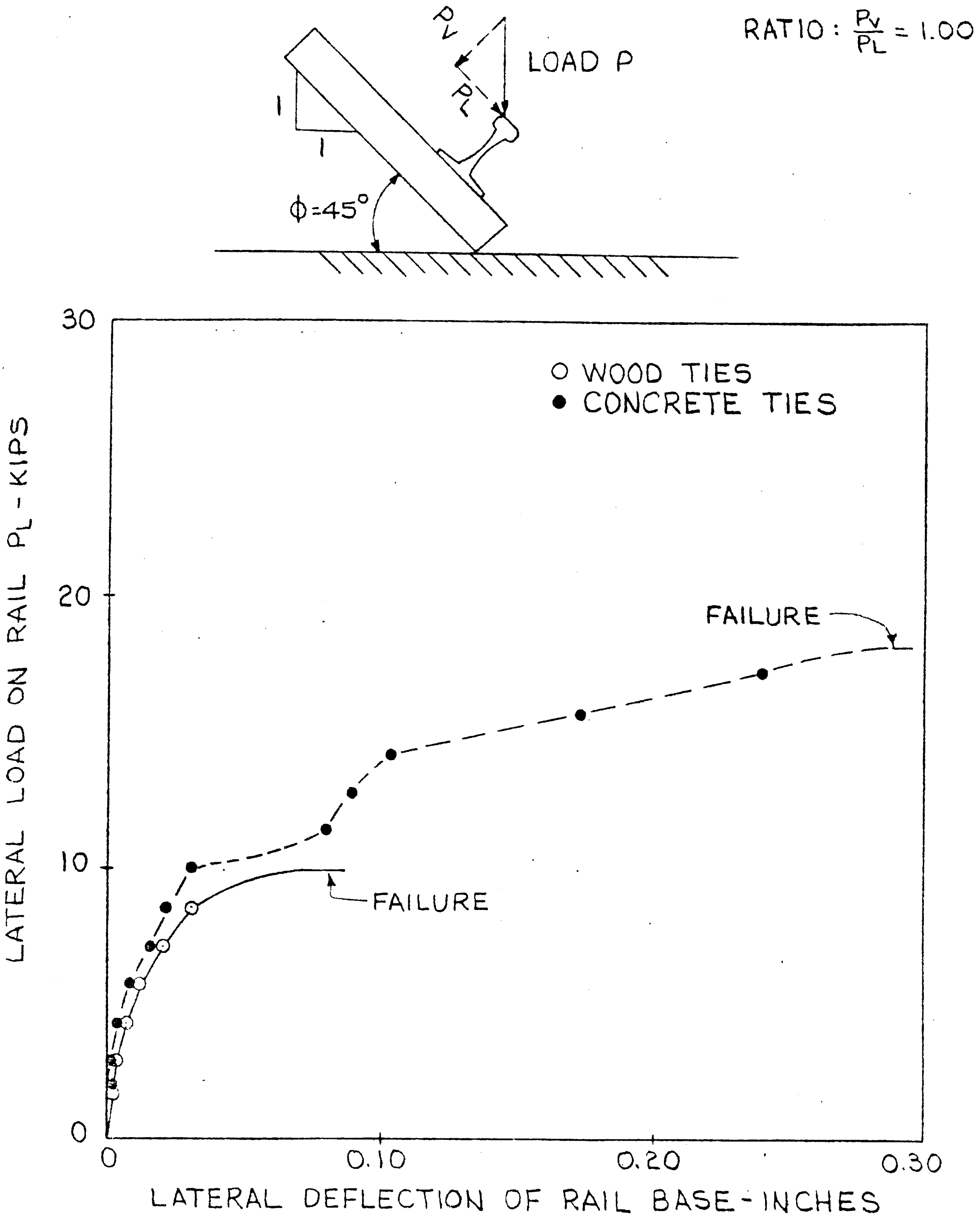
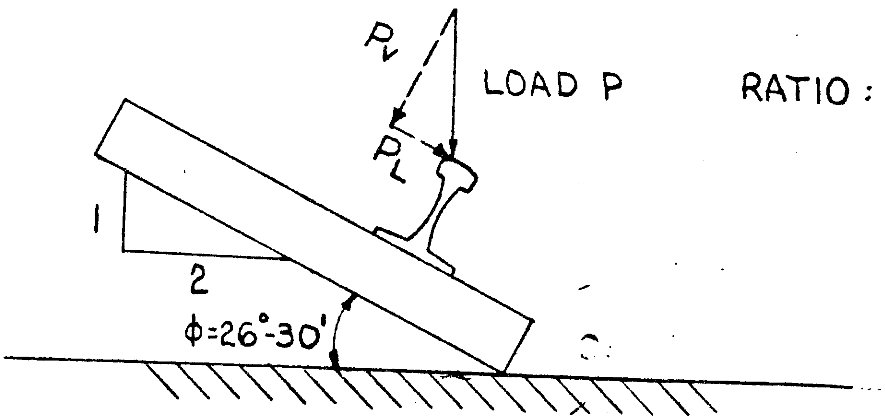


FIG. 9
RAIL OVERTURNING INVESTIGATION
DEFLECTION OF RAIL HEAD



RATIO : $\frac{P_V}{P_L}$ = 2.00

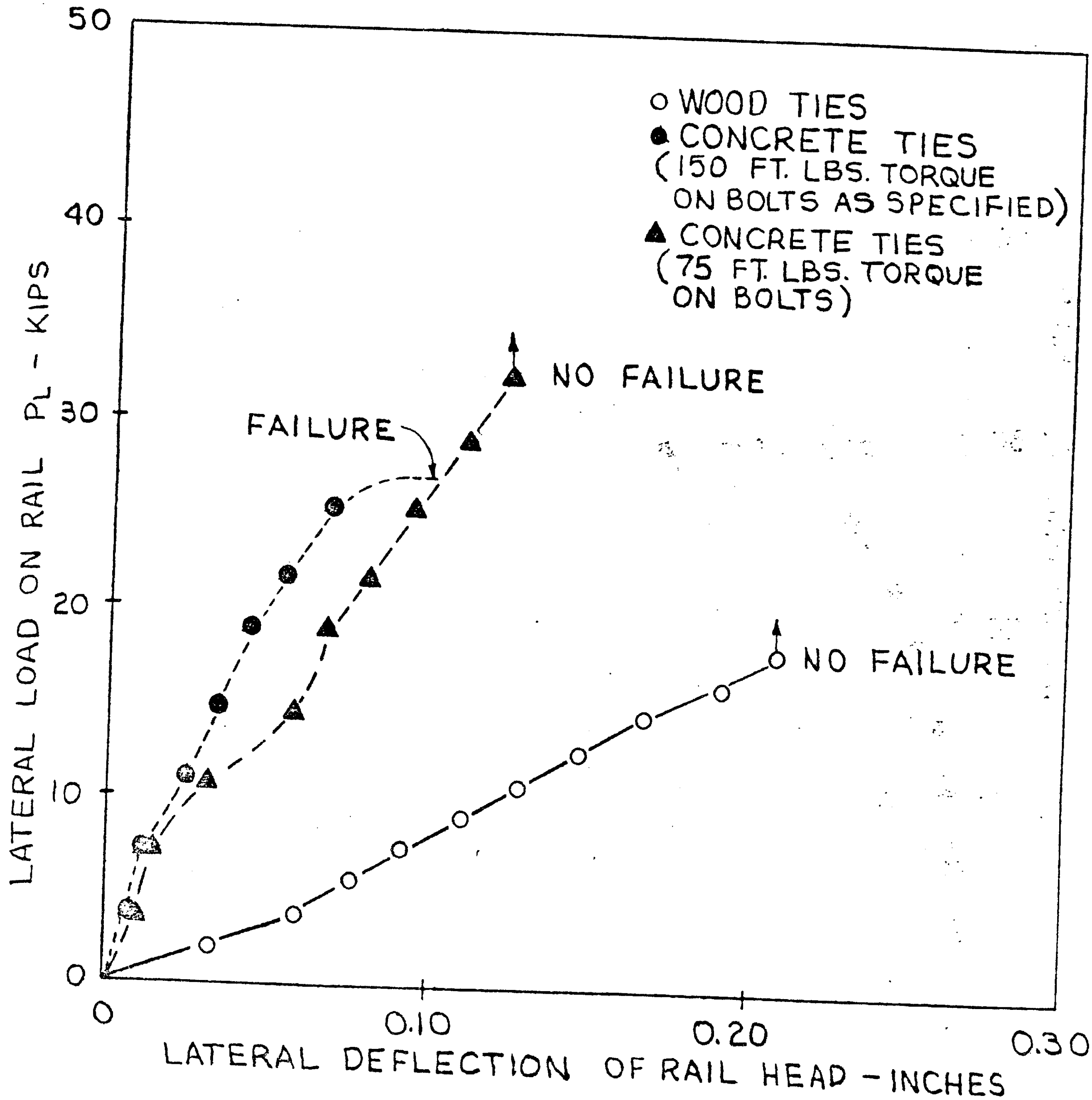


FIG. 10
RAIL OVERTURNING INVESTIGATION
DEFLECTION OF RAIL BASE

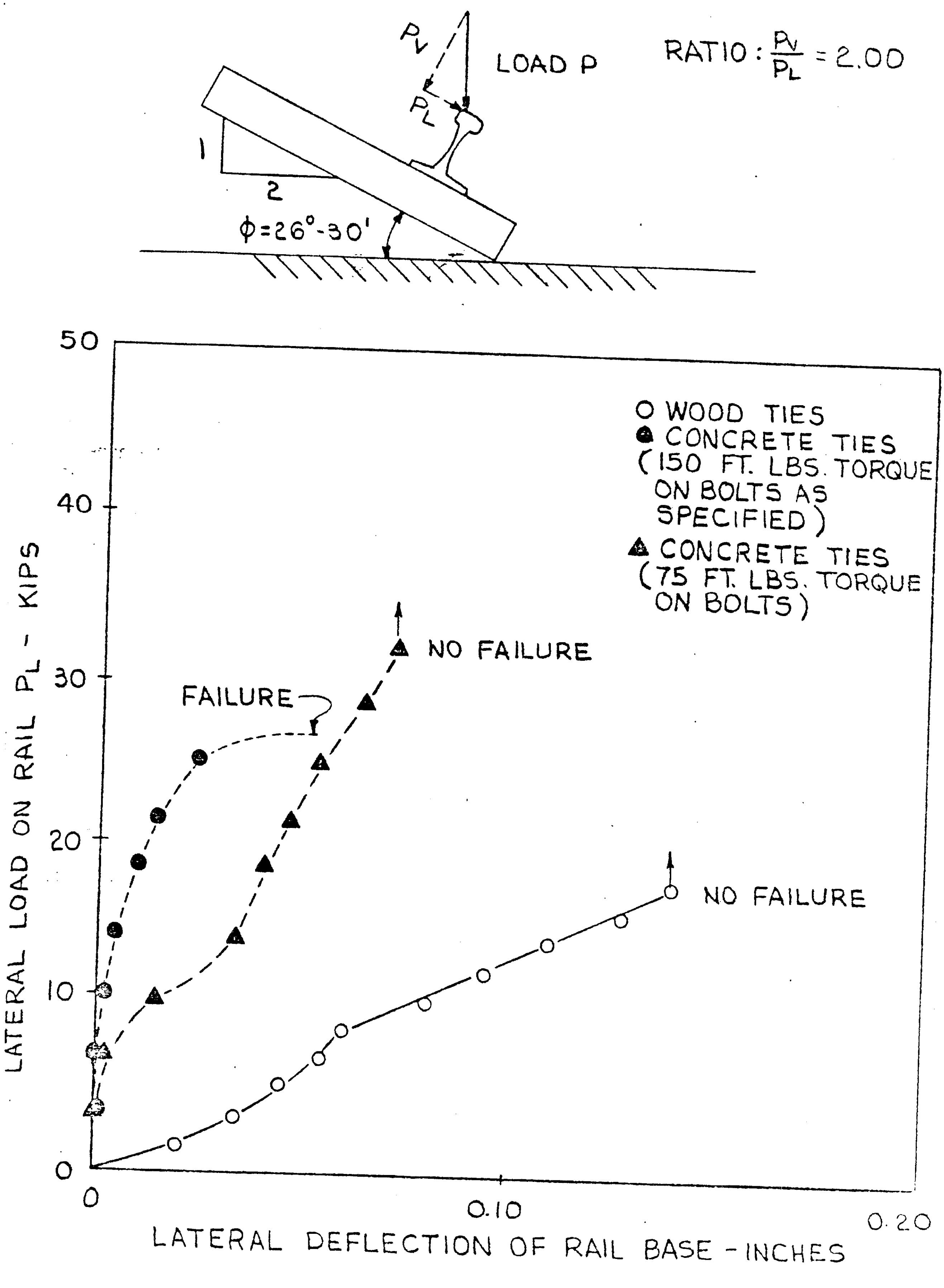


FIG. 11
RAIL OVERTURNING INVESTIGATION