FINAL REPORT

TESTING OF THE PEDESTRIAN SAFETY HANDRAIL

INDEX No. 520

By

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TESTING OF THE PEDESTRIAN SAFETY HANDRAIL (INDEX No. 520)

1.0 GENERAL

The Specification Office and the Roadway Design Office recommended an experimental study of the pedestrian safety handrails shown on the Roadway and Traffic Design Standards (Index No. 520). For a pedestrian hand railing system to be considered, it should meet all the AASHTO and the State/Local codes design criteria. The results of phase one of this experimental program recommended a full scale testing of two FDOT standard railings with three posts each. The testing will give the engineer more information about the overall behavior of these railings under the design loads. The results of the experimental program are presented in this report.

2.0 OBJECTIVE

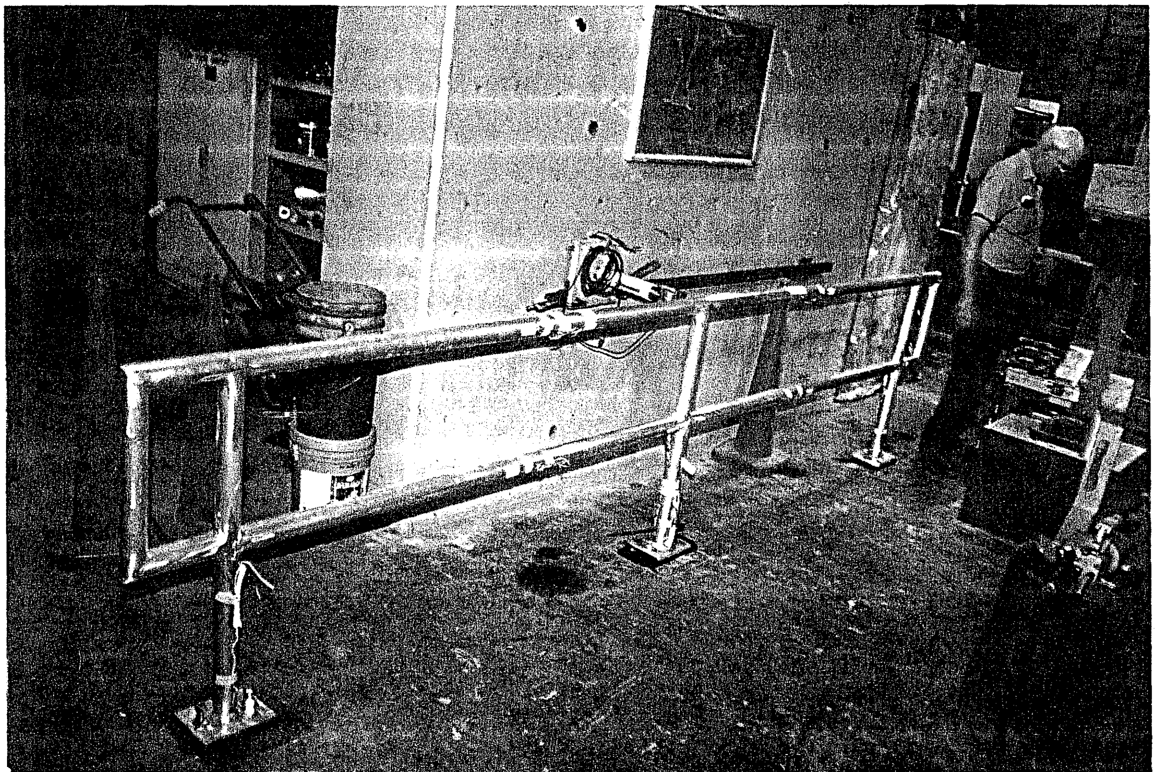
The objective of this testing program is to investigate the overall behavior of two standard FDOT railings. The results of moment vs. Deflection and strain as well as the ultimate loads and modes of failure will be presented and discussed in this report.

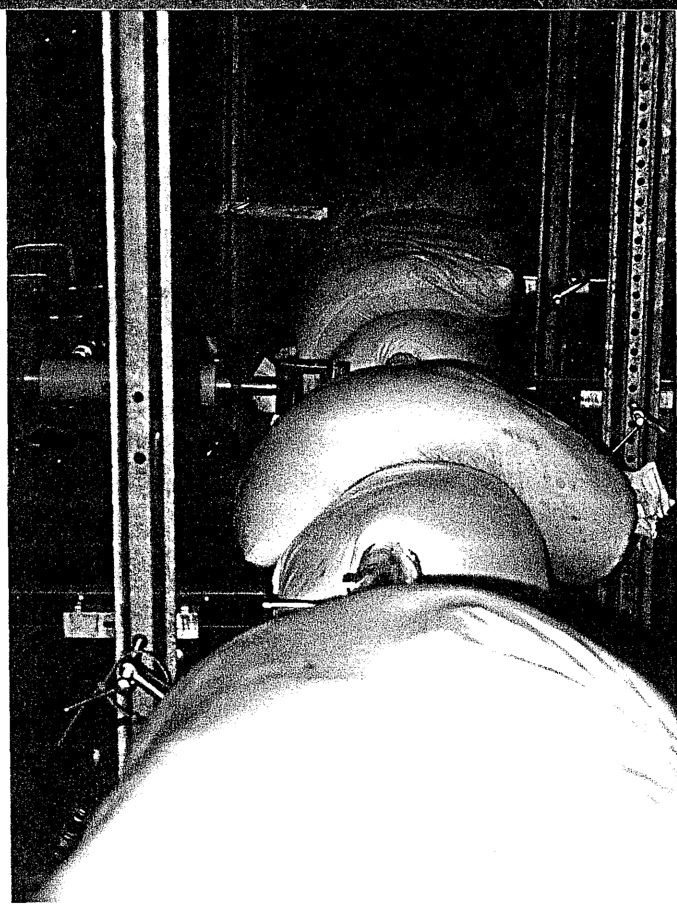
3.0 TEST SETUP AND INSTRUMENTATION

The post was bolted down at the base plate (6"x8"x1/2" base plate) with 2-1/2" diameter bolts. Rosette strain gages were installed at 1" from the base plate on the tension and compression sides of the post as well as at other critical railing locations. A load cell to measure the load and an LVDT (Linear Voltage Differential Transducer) to measure the deflection under the loading point were used in this test. All gages were connected to an Optim Electronic high speed Data Acquisition system to collect and store the data for later analysis. See Figures 1 through 3 for a typical test setup and instrumentation.

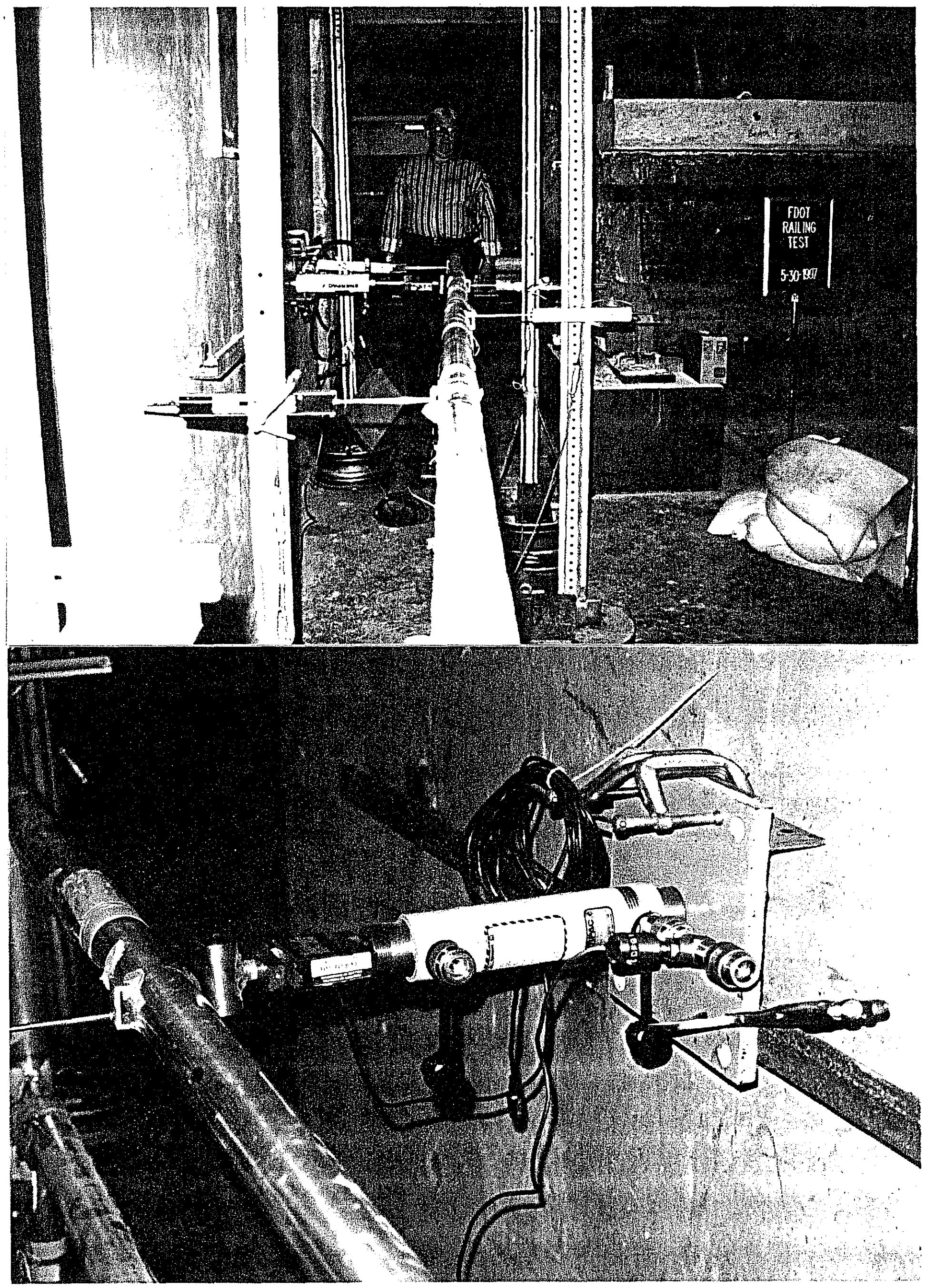
4.0 PROCEDURE

The rails were loaded in small load increments up to the service load of 325 lbs. and then to 600 lbs. in the horizontal direction at 37.5" from the base. The maximum applied load is based on a design load w = 50 lb/ft (Sand bags on top rail) applied in the vertical direction, and an allowable post spacing of 6.5 ft. Then unload the post and check for any permanent set. This test was performed by applying the load to the middle post and the middle of top beam. Reload the post with the same procedures as before till failure occurred. Rail #1 was tested to failure by applying the load at the middle post. Also, rail #2 was tested to failure by applying the load at the middle of top beam between the posts. All strains, deflections and load data were recorded and stored by the Data Acquisition system.

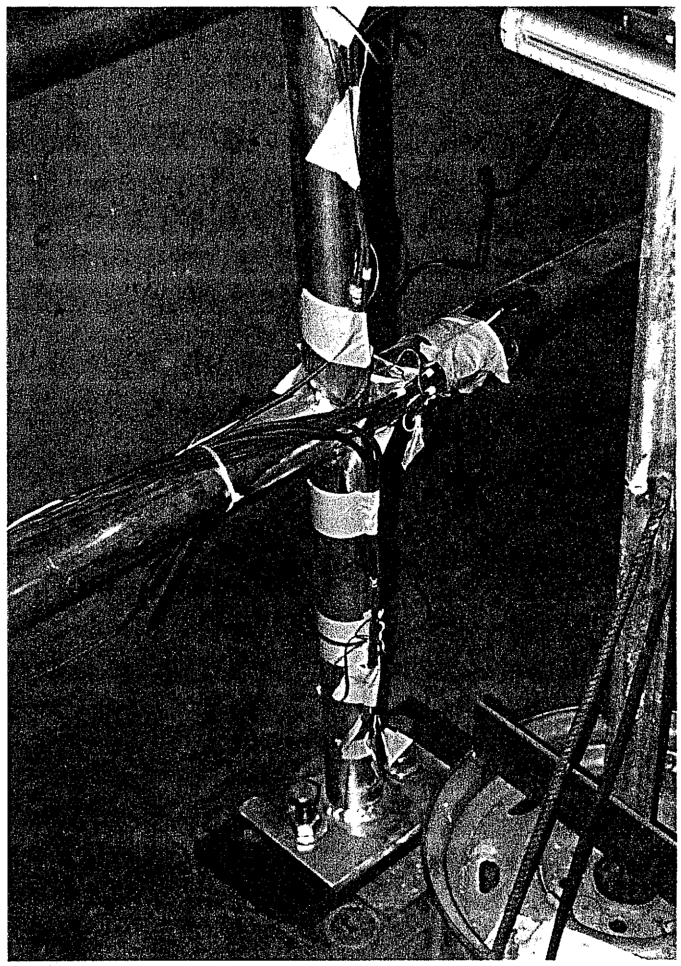




GENERAL TEST SETUP
FIGURE 1



LOAD CELL AND LVDT INSTRUMENTS
FIGURE 2



BASE PLATE AND ROSETTE STRAIN GAGES
FIGURE 3

5.0 Material Properties

Aluminum 6061-T6

Specific Weight, γ = 170 lb/ft^3, (26 kN/m^3)

Mass Density, ρ = 5.4 slug/ft^3, (2700 kg/m^3)

Modulus of Elasticity, E = 10,000 ksi, (70 Gpa)

Shear Modulus of Elasticity, G = 3,800 ksi, (26 Gpa)

Poisson's ratio, ν = 0.33 LRFD/AA.

Yield Stress, σ_y = 40 ksi, (270 MPa) 35

Ultimate Stress, σ_u = 45ksi, (310 MPa) 42

6.0 Railing Load

The Pedestrian hand railing posts shall be designed for a transverse load of wL (where L is the post spacing) acting at the center of gravity of the upper rails. The maximum applied load is based on a design load w = 50 lb/ft, and an allowable post spacing of 6.5 ft.

w = 50 lb/ft

Post height = 37.5 in.

Post spacing = 6.5 ft.

Loading on top of Post = 50 x 6.5 = 325 lbs.

7.0 Results of Test Specimens

The results for deflections, strains and the modes of failure will be presented and discussed for each Rail.

7.1 Rail Test #1

Material : Aluminum 6061-T6
Outside Diameter : 2.59"
Thickness : 0.199"
Moment of Inertia : 1.076 in^4.
Section Modulus : 0.831 in^3.

≃ ϕ 2.5" Tube
0.219 wall ~ 0.188 ?

Design/Service Loads: 325 ?

Maximum Deflection at 300 lbs, $\delta_{exp.}$ = 0.500 in.
Maximum Bending Stress at 300 lbs, $\sigma_{exp.}$ = 9,500 lb/in^2
Yield Stress of rail, σ_y = 40,000 lb/in^2.
σ_{max} / σ_y = 23.8 % of the yield strength of the rail

For Load Test #2 shouldn't service load be 50 lb/ft × 2 × 6.5 ft = 650 lbs.

Ultimate/Failure Loads:

Ultimate load = 1227 lbs.
Ultimate Deflection, $\delta_{max.}$ = 2.437 in.

Mode of Failure :

Failure of weld at base plate (See Figure 4 below)

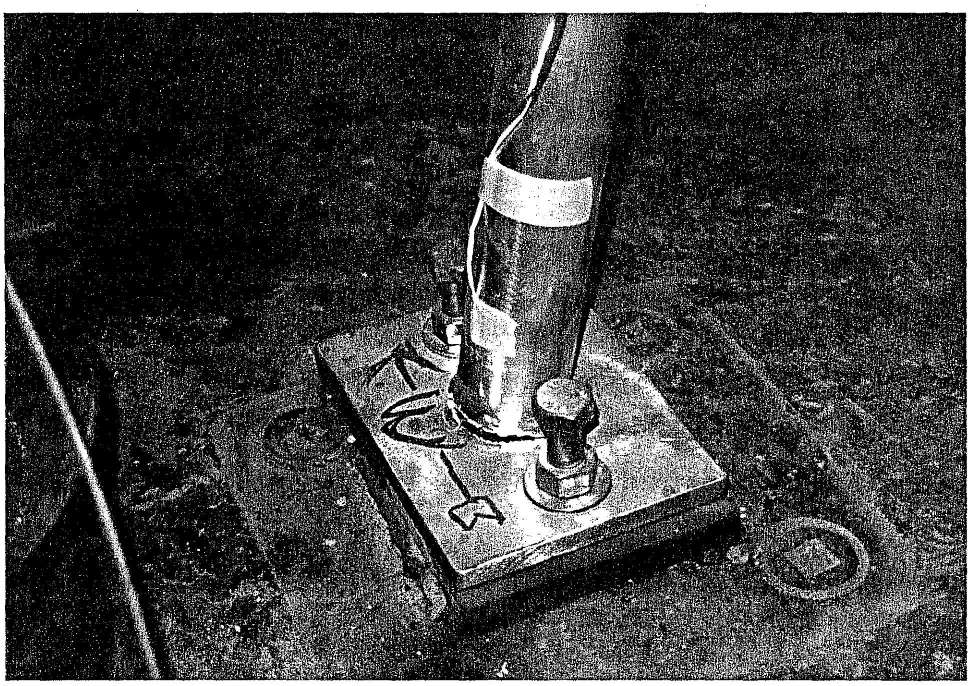


FIGURE 4

Load vs. Deflection

Rail #1
Centerline Load Point

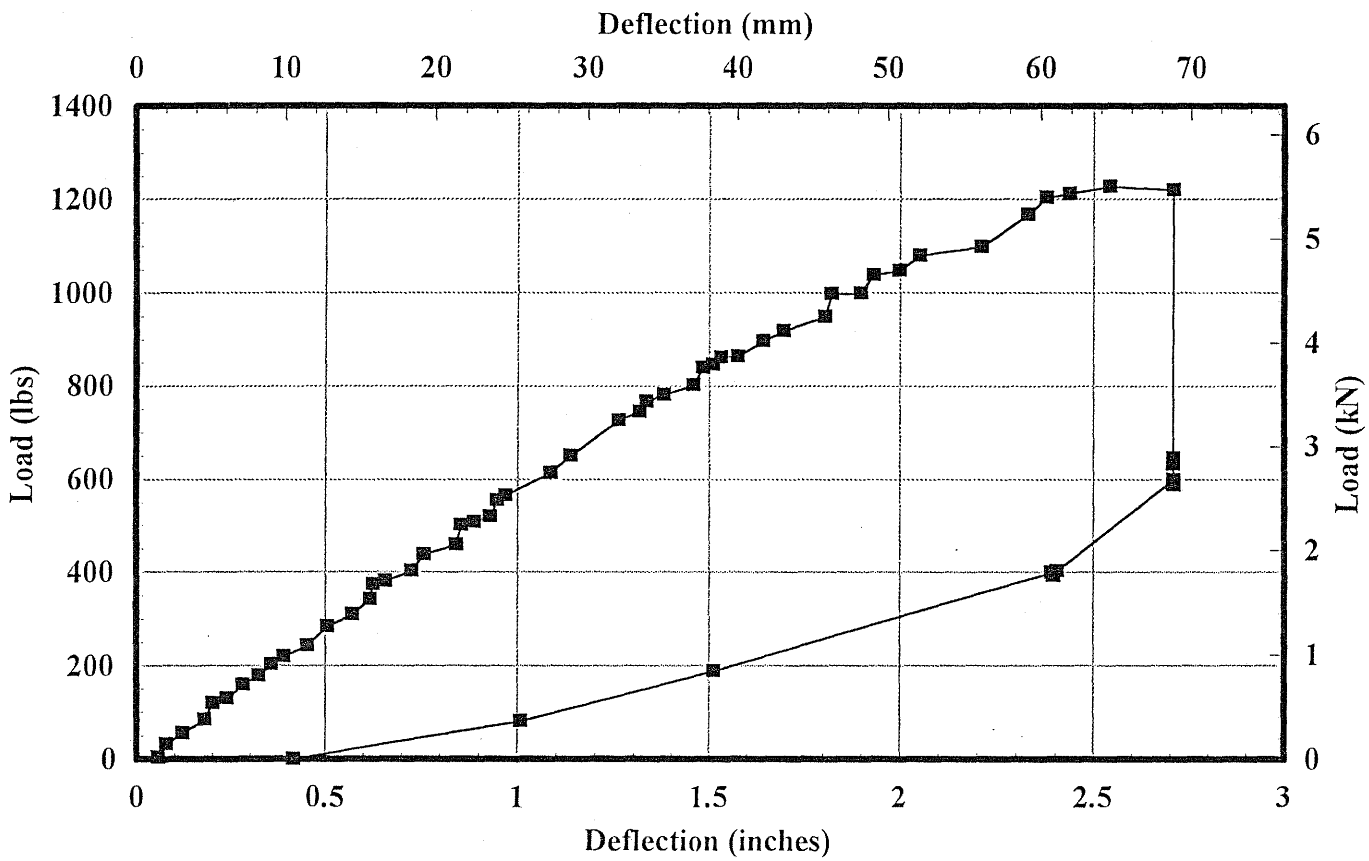


FIGURE 5

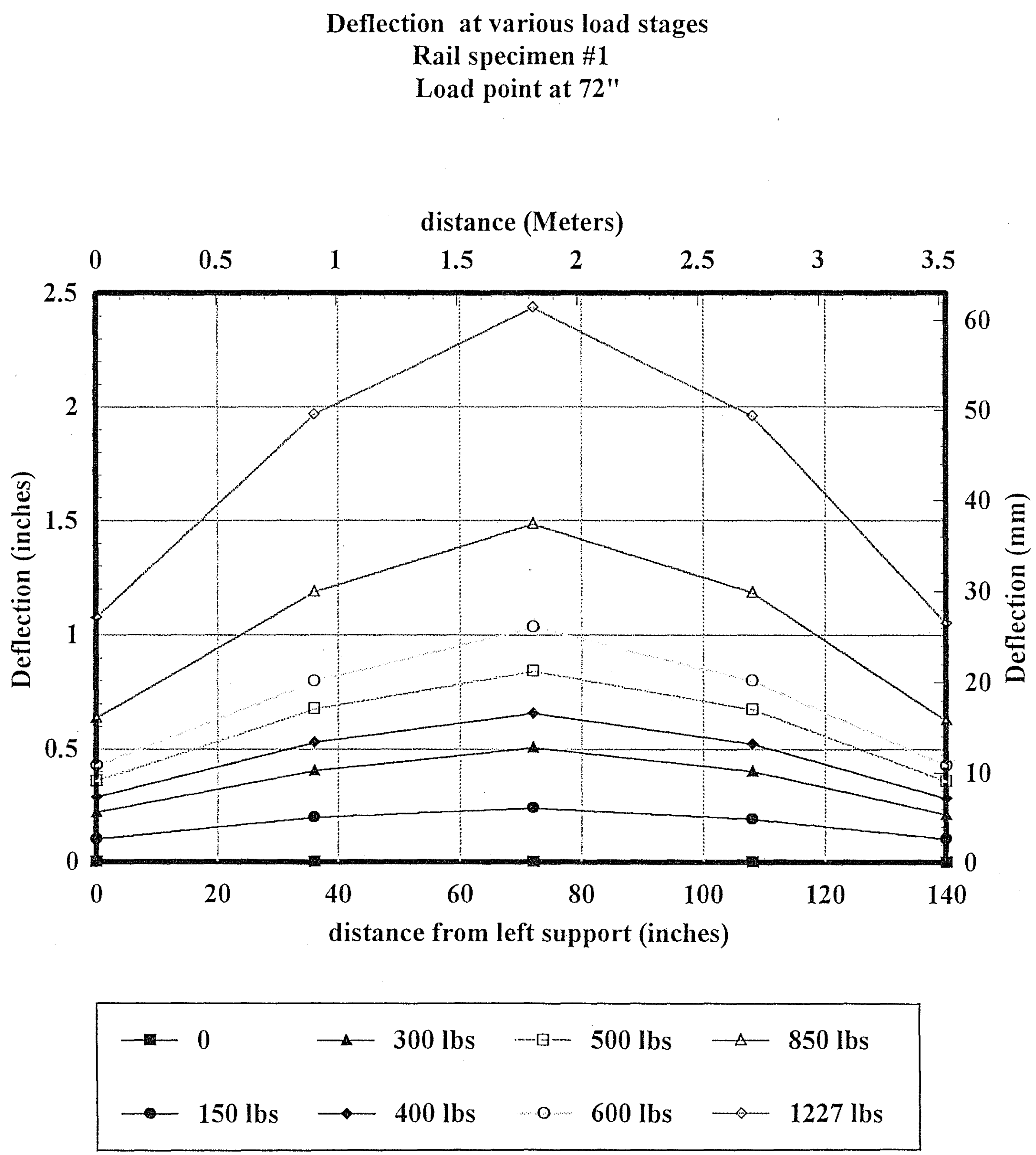

Deflection at various load stages
Rail specimen #1
Load point at 72"
distance (Meters)
0
0.5
1
1.5
2
2.5
3
3.5
Deflection (inches)
2.5
2
1.5
1
0.5
0
Deflection (mm)
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
distance from left support (inches)
0
300 lbs
500 lbs
850 lbs
150 lbs
400 lbs
600 lbs
1227 lbs

FIGURE 6

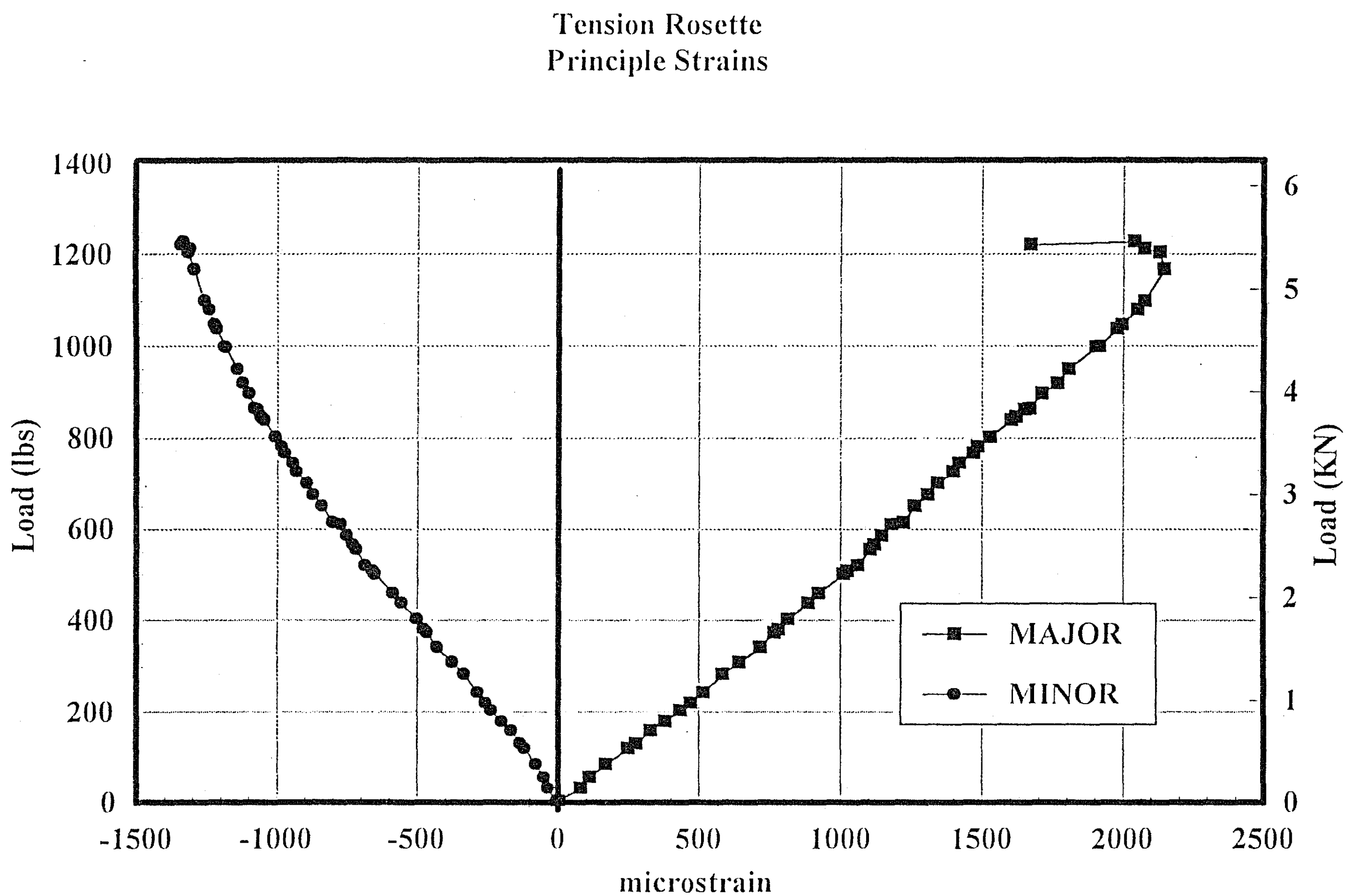

Tension Rosette
Principle Strains
Load (lbs)
1400
1200
1000
800
600
400
200
0
-1500
-1000
-500
0
500
1000
1500
2000
2500
microstrain
Load (KN)
6
5
4
3
2
1
0
MAJOR
MINOR

FIGURE 7

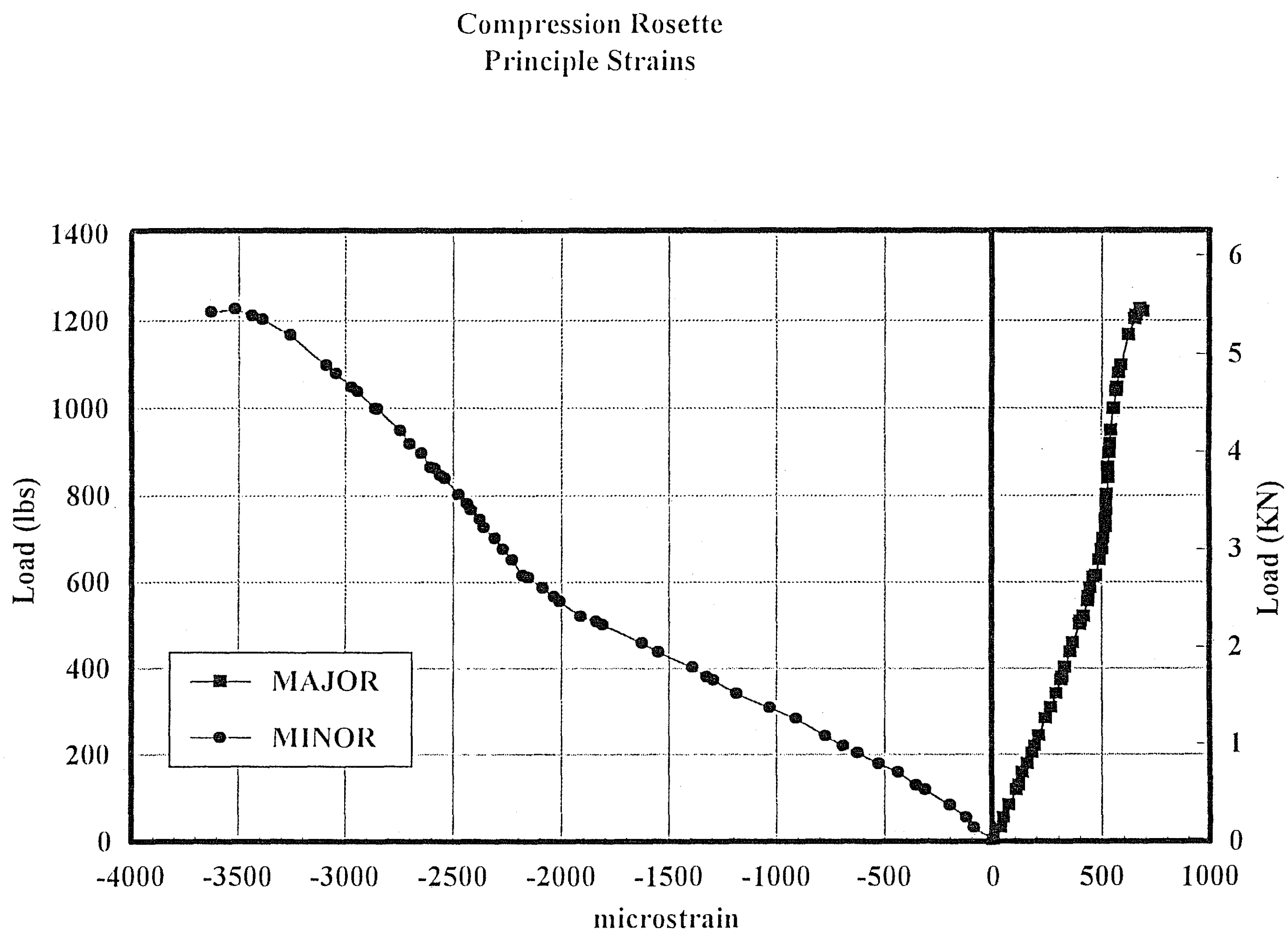

Compression Rosette
Principle Strains
Load (lbs)
1400
1200
1000
800
600
400
200
0
Load (KN)
6
5
4
3
2
1
0
MAJOR
MINOR
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
microstrain

FIGURE 8

7.2 Rail Test #2

Material	: Aluminum 6061-T6
Outside Diameter	: 2.369"
Thickness	: 0.154"
Moment of Inertia	: 0.660 in^4.
Section Modulus	: 0.558 in^3.

Design/Service Loads:

Maximum Deflection at 300 lbs, $\delta_{exp.}$ = 0.321 in.

Maximum Bending Stress at 300 lbs, $\sigma_{exp.}$ = 1,500 lb/in^2

Yield Stress of rail, σ_y = 40,000 lb/in^2.

σ_{exp} / σ_y = 3.8 % of the yield strength of the rail.

Ultimate/Failure Loads:

Ultimate load = 1480 lbs.

Ultimate Deflection, $\delta_{max.}$ = 2.754 in.

Mode of Failure :

Failure of weld between post and base plate (See Figure 9 below)

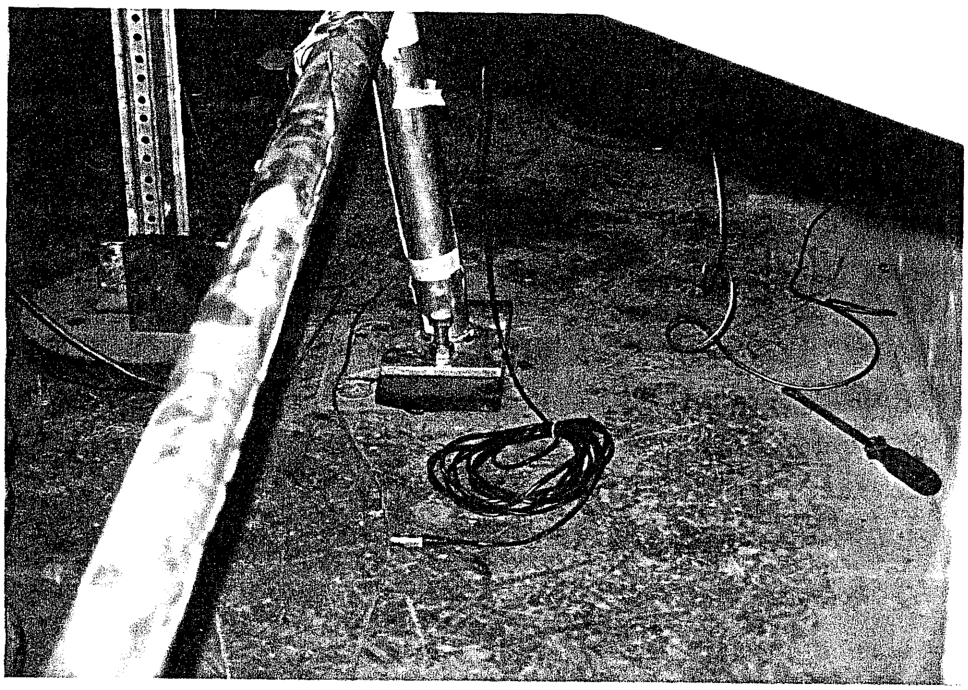


FIGURE 9

Deflection vs Load
at Load Point
Railing #2

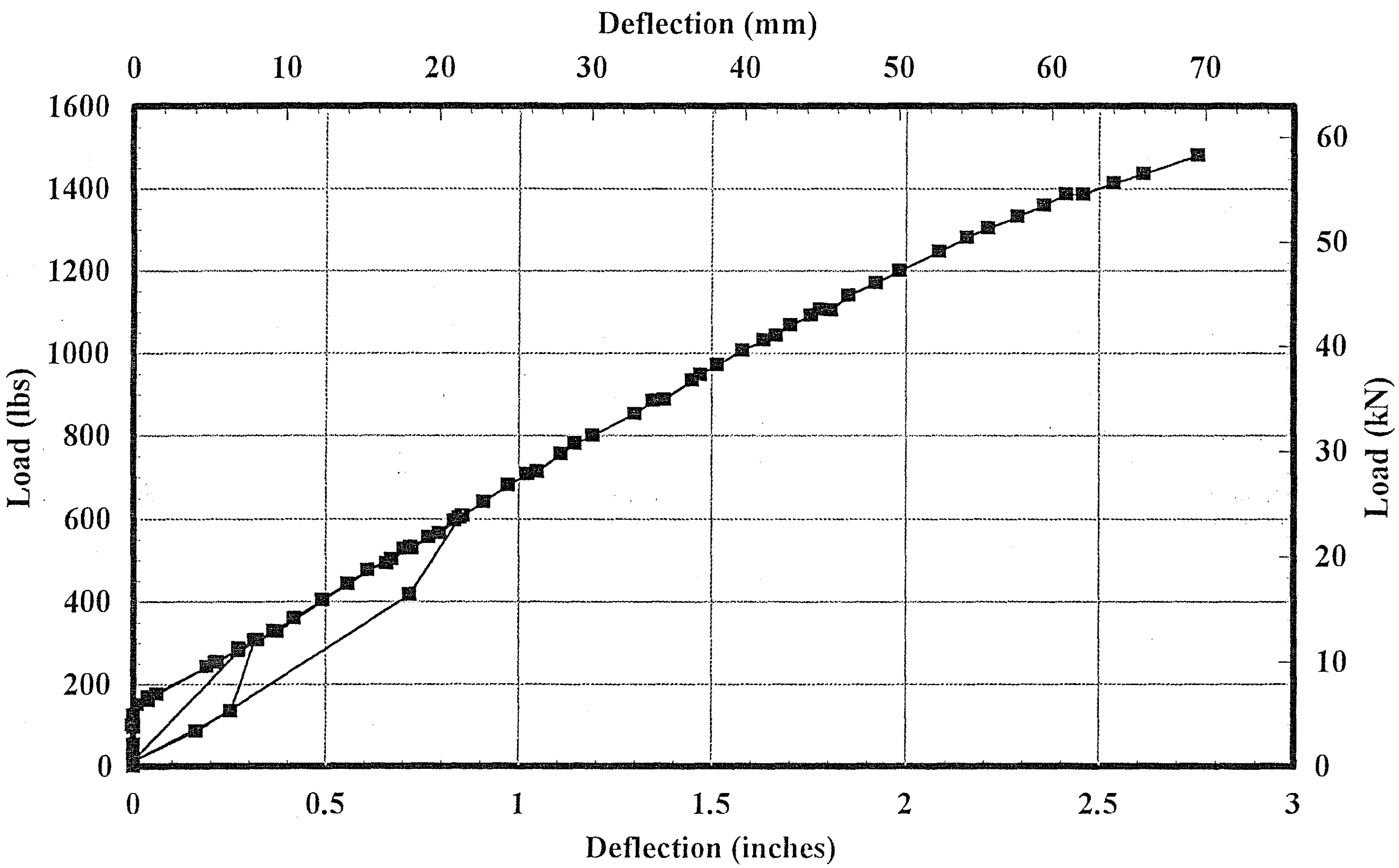


FIGURE 10

Deflection at various load stages
Rail specimen #12
Load point at 108"

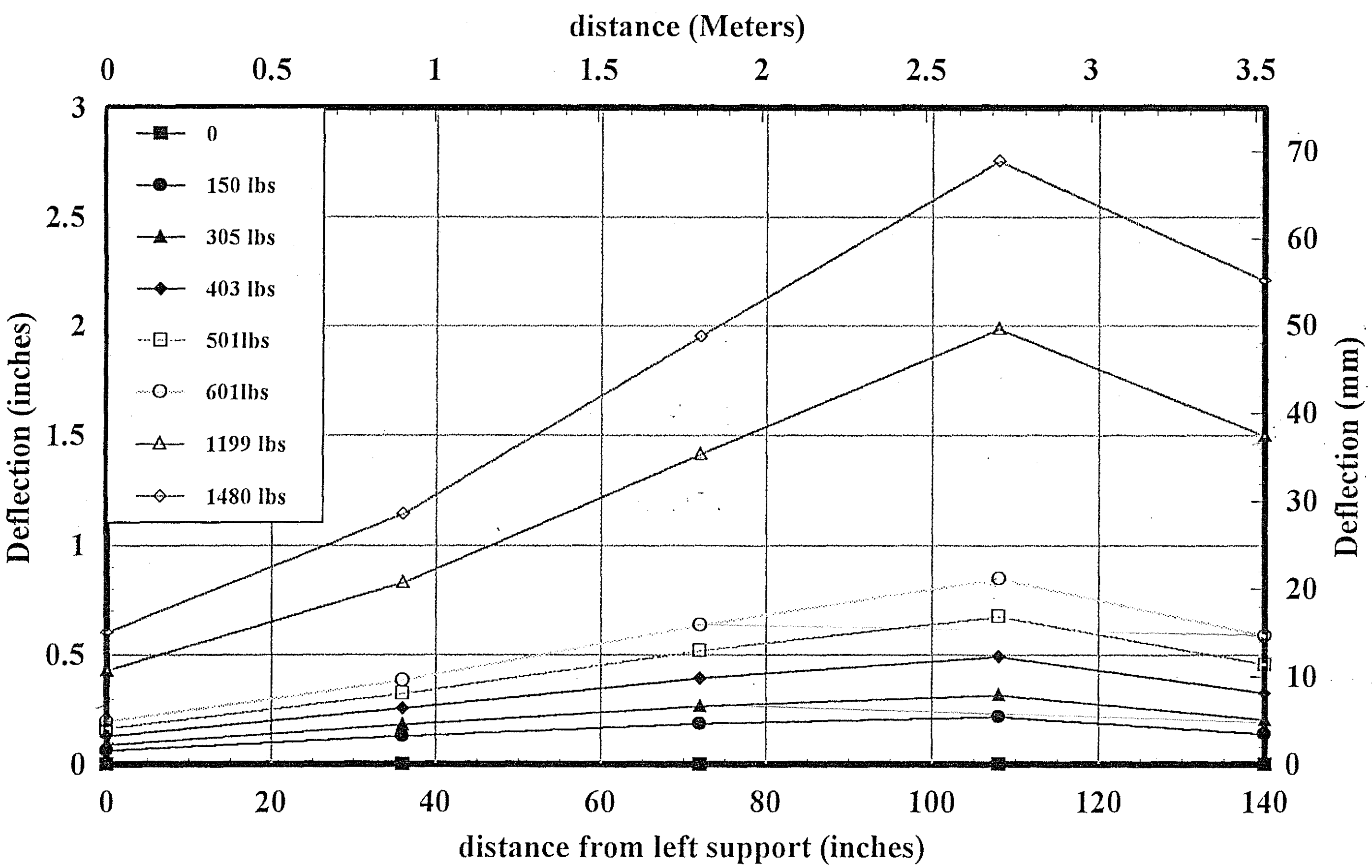


FIGURE 11

Compression Rosette
Principle Strains

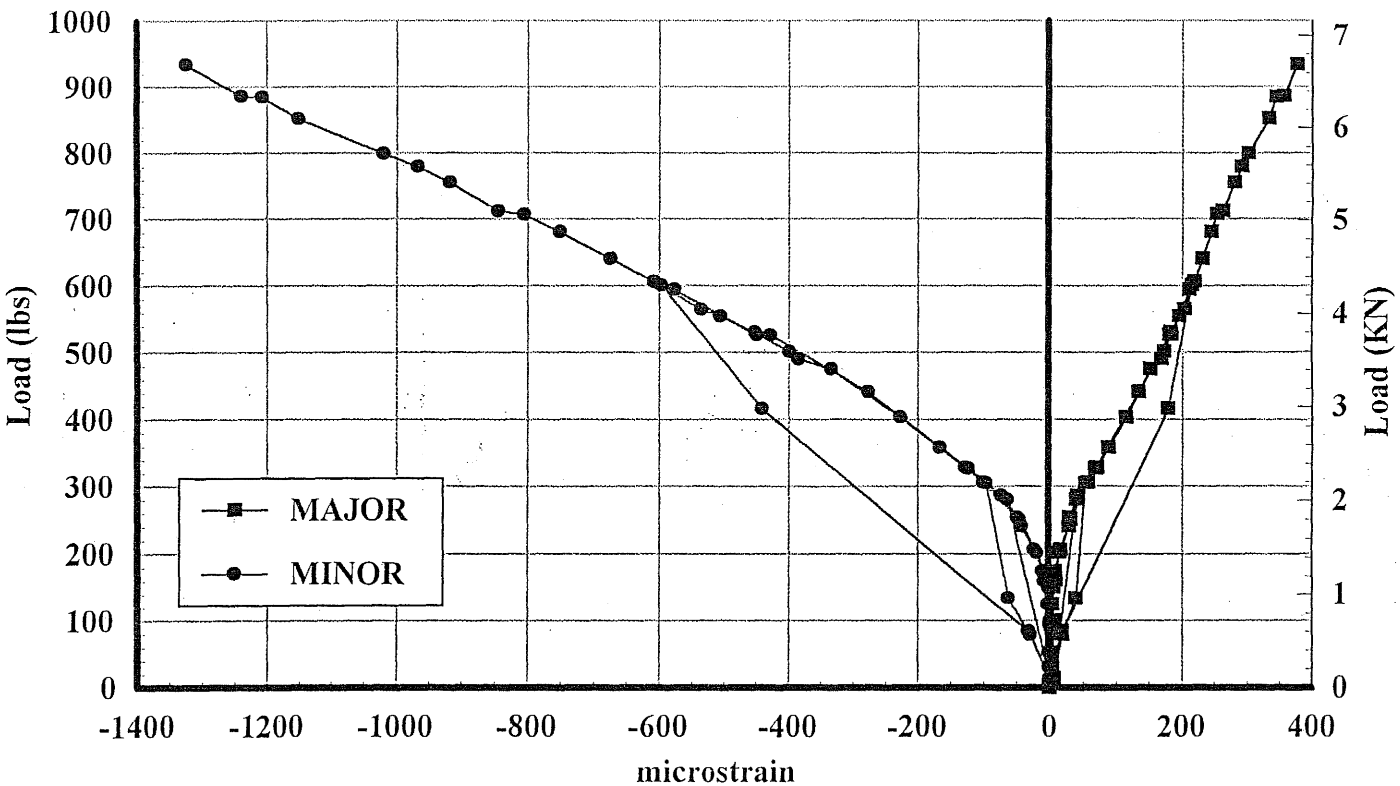


FIGURE 12

Tension Rosette
Principle Strains

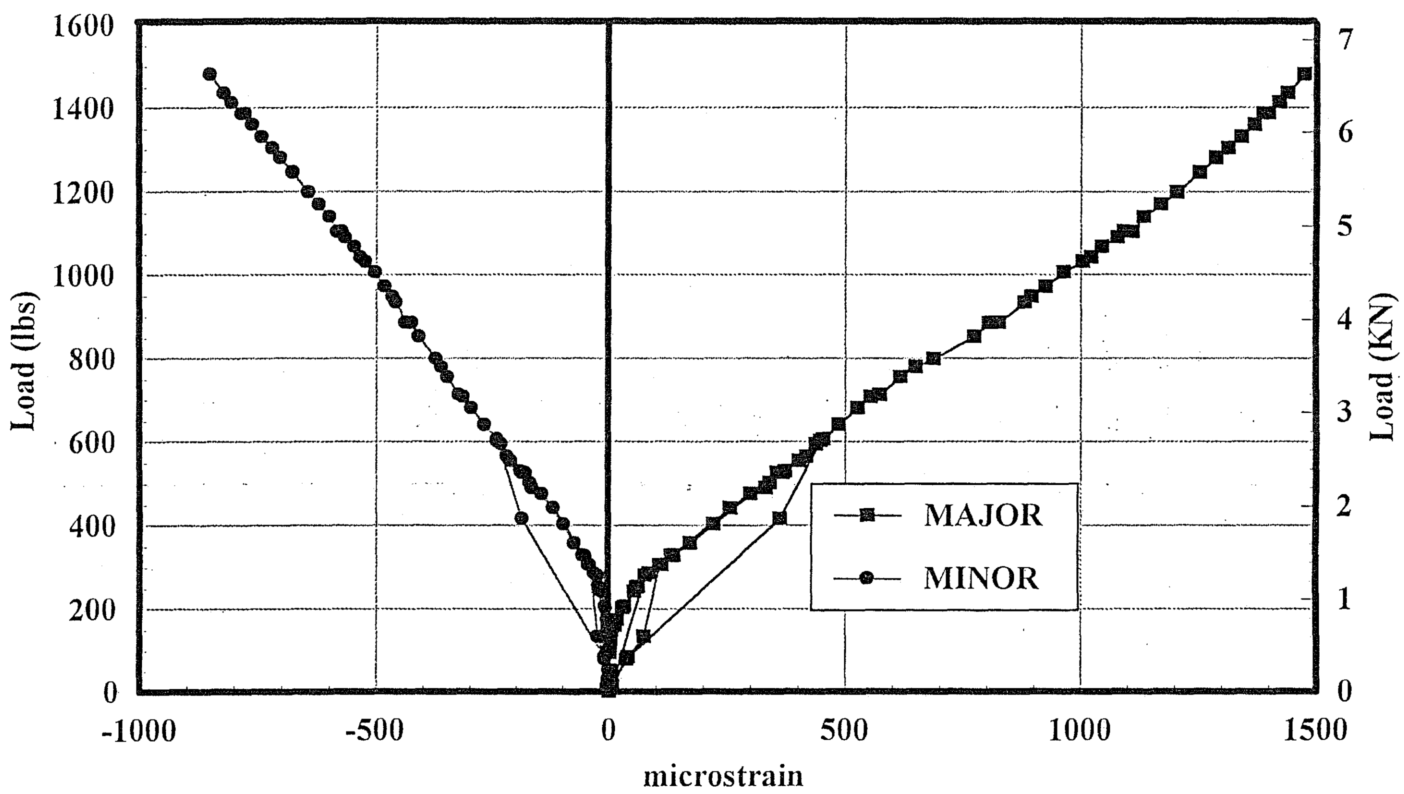


FIGURE 13

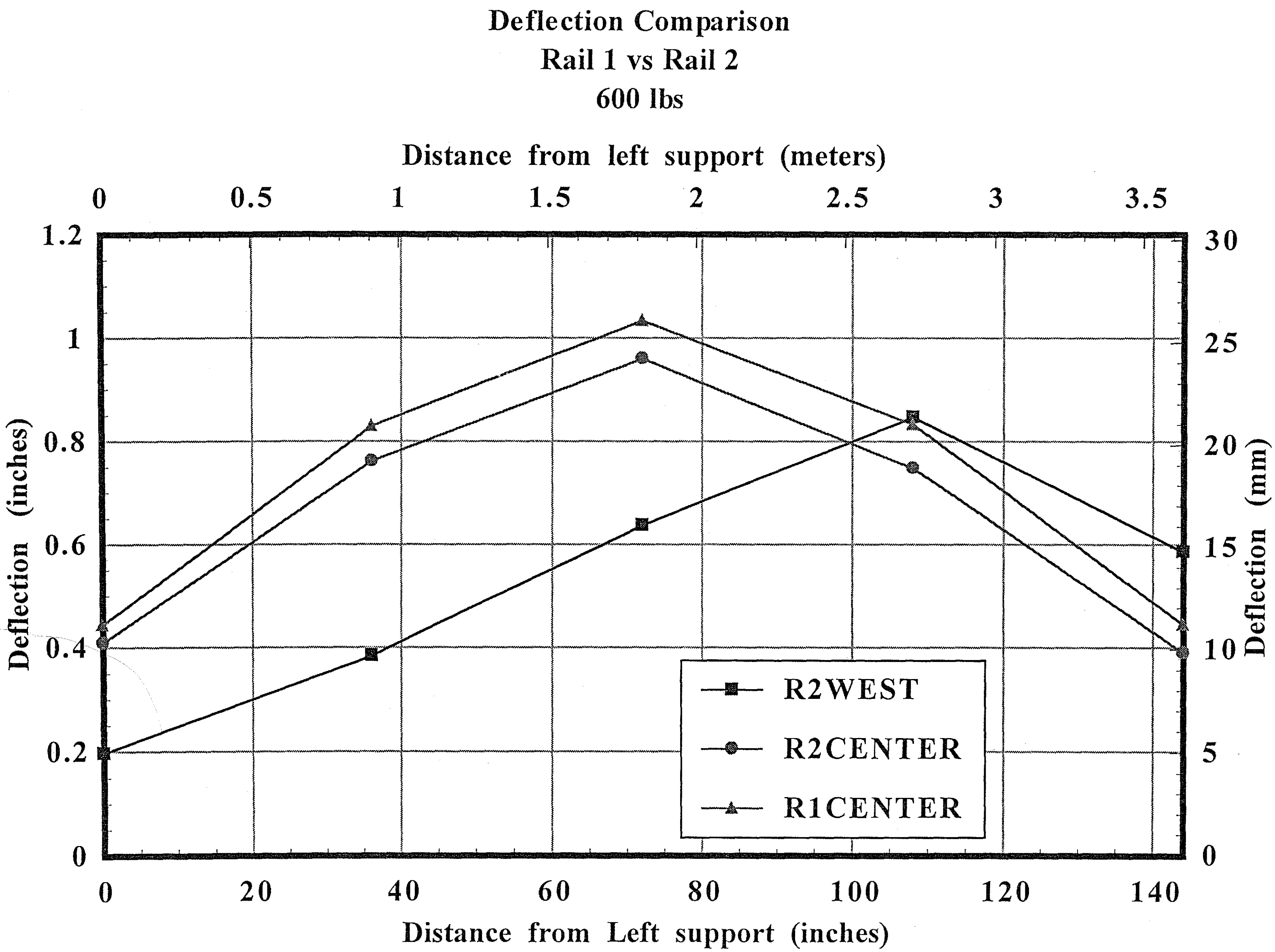
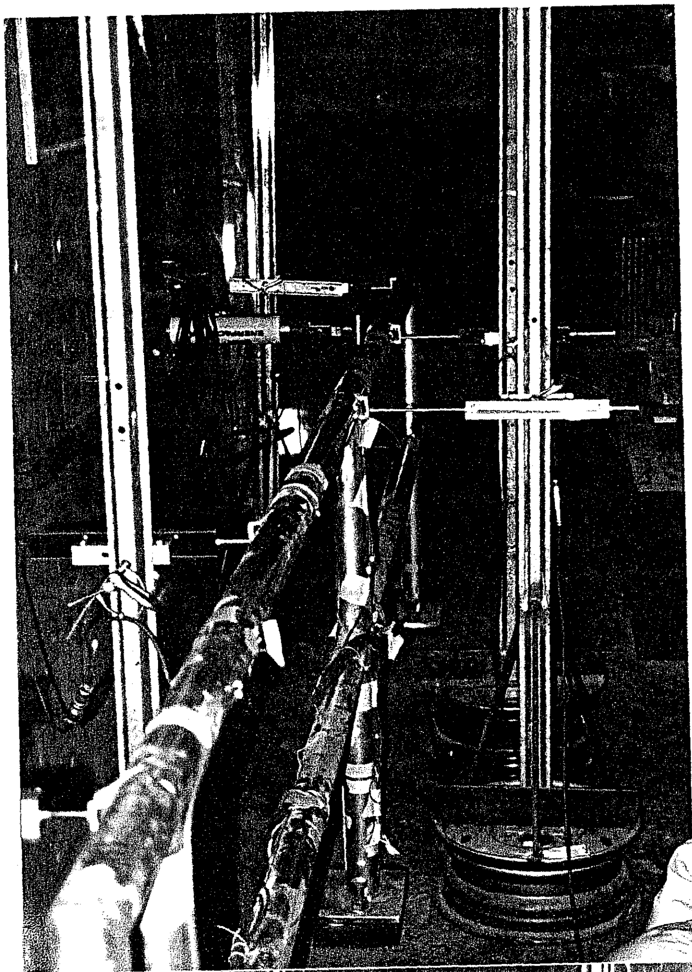
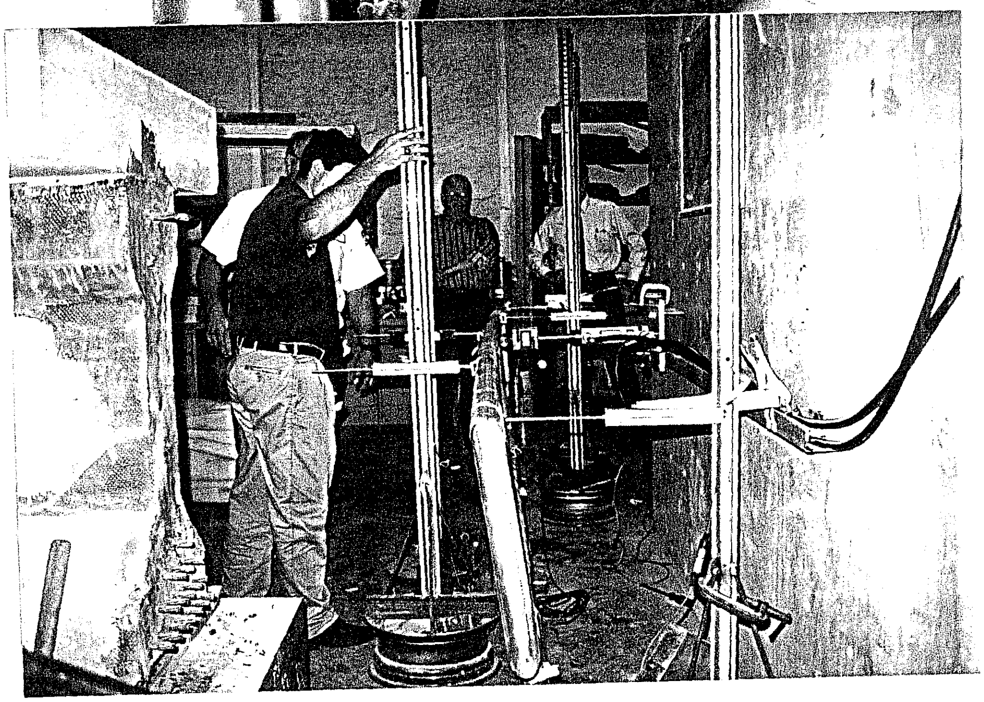

Deflection Comparison
Rail 1 vs Rail 2
600 lbs
Distance from left support (meters)
0
0.5
1
1.5
2
2.5
3
3.5
Deflection (inches)
1.2
1
0.8
0.6
0.4
0.2
0
Deflection (mm)
30
25
20
15
10
5
0
R2WEST
R2CENTER
R1CENTER
0
20
40
60
80
100
120
140
Distance from Left support (inches)

FIGURE 14





TESTED RAILS
FIGURE 15

8. CONCLUSION AND RECOMMENDATION

The test results showed that the tested rails were in full compliance with the AASHTO and FDOT loading requirements.

- The weld between the post and the base plate controls the mode of failure for both rails. The weld failed before the yielding of the section.
- All the railing welds met the service loading conditions with a 3.5 factor of safety.
- The service load was applied and removed at different locations without any permanent deformations.
- Use 6"x8"x1/2" aluminum base plate anchored with 2-1/2"ϕ anchor bolts with 6" minimum embedment.
- Both rails performed very well under the test. It is recommended to use the section properties of rail #2. but load was shared by two posts. since mid span loading.

9. ACKNOWLEDGMENTS

The support and cooperation of the staff at the FDOT/Structural Research Center (FDOT/SRC) made the testing possible. The Author thanks them all.