TEXAS
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TEXAS
HIGHWAY
DEPARTMENT

COOPERATIVE
RESEARCH

DEVELOPMENT OF BREAK-AWAY SIGN SUPPORTS AND SLOTTED STEEL PLATE MECHANICAL FUSES

in cooperation with the
Department of Transportation
Federal Highway Administration
Bureau of Public Roads

RESEARCH REPORT 68-4 (FINAL)
STUDY 2-5-63-68
SIGN SUPPORT STRUCTURES

DEVELOPMENT OF BREAK-AWAY SIGN SUPPORTS AND SLOTTED STEEL PLATE MECHANICAL FUSES

by

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Research Report Number 68-4 (Final)

Research Study Number 2-5-63-68
Sign Support Structures

Sponsored by
The Texas Highway Department

In Cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

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TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
College Station, Texas

FOREWORD

This report constitutes the fourth and final report of Research Study 2-5-63-68 (Sign Support Structures). The first report, "Impact Behavior of Sign Supports," presented the results of the first 12 of 43 crash tests conducted in conjunction with this study. Also, detailed descriptions of the development of test procedures and break-away concepts were included in this report. Since crash research was in a relatively embryonic stage at the time, the principal method of analysis was phenomenological by nature, describing the phenomena of vehicle-sign support interaction as observed on the high speed motion picture films of the crash tests. Also, some of the earliest attempts at electronic instrumentation were reported.

In this first report it was pointed out that three primary characteristics of sign supports contribute most significantly to the severity of vehicular collision:

(1) The mass of weight of the sign support,

(2) The flexural rigidity or stiffness of the support, and,

(3) The condition of fixity at the base.

It follows that the objectives of the research were to design and test sign supports (1) with substantial reduction in the total mass involved, (2) which themselves will yield under the impact of collision, and (3) which will readily disconnect from their foundations when struck by a vehicle.

Two basic design concepts were presented in the first report: the "braced-leg" or "A-frame" structure and the "unbraced post support" with a slip base. The latter is now used throughout the country. Both design concepts offered considerable potential from the safety standpoint, but the unbraced post was favored because it was a much "cleaner" design, offering fewer complications in specifications and detailed design, and finally, fewer maintenance problems.

The second report, "Impact Behavior of Sign Supports—II," prepared in two parts, presented the results of the final 31 crash tests conducted in conjunction with the study (Part A). Part B presented the results of electronic instrumentation of three of the crash tests and the preliminary development of a mathematical model to describe analytically the vehicle-support interaction of the collision phenomena.

Part A of the report dealt mainly with the phenomenological behavior of the slip base design under various conditions of impact. For the larger supports (8WF31), a test was conducted to ascertain the impact behavior at an approach angle of 15 degrees. Numerous tests were conducted to determine the impact behavior of small "EXIT" signs where the vehicle could strike either one or both of the supports at various speeds and angles of impact. Also, several tests were conducted using single and double pipe supports under various conditions. Whereas the fuse plate or "plastic hinge" was used effectively in the two-post supports, it was not functional and was not a necessary item in the 3- and 4-inch pipe supports.

Two tests were conducted using wood post supports for the "EXIT" type sign. One design, known as the "Pennsylvania Design" utilized wood posts notched to effect break-away action. The other design, referred to as the "TTI Design" was characterized by a slot across the neutral axis of the post just below bumper level to serve as a "stress riser" under impact loading conditions.

Part B of the report presented the results of an analytical study of the break-away sign supports. It was a detailed report on three tests using electronic instrumentation on the vehicle and the post. Analysis techniques were described and a comparison was made of data gathered by photo instrumentation and by electronic instrumentation.

Observations of the high-speed films of the crash tests led to the development of a mathematical model to analytically describe the impact behavior of the support including the slip base and the hinge joint. The principal considerations in the development of the model are reported along with a comparison of model data with data from photo and electronic instrumentation.

The third research report prepared in conjunction with this study was entitled "Instrumentation and Photographic Techniques for Determining Displacement, Velocity Change, and Deceleration of Vehicles with Break-Away Sign Structures." The general objective of this phase of the research was to produce a time dependent description of vehicle and break-away support post behavior during a collision incident. In addition to the general objective, the specific objectives were:

(1) to develop a technique for acquiring and reducing high-speed film data of the collision incident,

(2) to develop a technique for reducing and analyzing data from an accelerometer mounted on the frame of the crash vehicle,

(3) to correlate the information from the two data gathering systems, and

(4) to determine the force in the support post at bumper height during the collision incident.

The fourth and final report of the study, entitled "Laboratory Tests of Slotted Steel Plate Mechanical Fuses," presents test data on a modification of the original Texas Break-Away Design. As described in Research Reports 68-1 and 68-2, a "hinge joint" was placed in the support post approximately seven feet above the base, or more specifically, near the bottom edge of the sign face. This hinge joint permitted the lower portion of the post to fold up out of the path of the vehicle. Originally, the hinge joint was formed by cutting the front flange and the web of the post, then reconnecting the front flange with a bolted cast iron "fuse plate." The "fuse plate" was intended to fracture as the result of a collision with the post; however, premature fractures were observed in several cases due to casting imperfections, excessive stresses due to bolting, and various other reasons.

D. L. Hawkins of the Texas Highway Department proposed a slotted steel plate to replace the cast iron plate. Laboratory tests were conducted to establish the relationships of bolt tension, bolt size, and plate thickness typical of representative post sizes of Texas Highway Department Design Standards.

This study has been one of the most successful research studies ever conducted in the cooperative research program. As physical evidence, the Texas Highway Department completely revised their design standards for sign supports—and in fact, their design philosophy—on the basis of the results of this research. In addition, many other states have adopted similar break-away standards. Also, the break-away concept and the new design philosophy has "spilled over" into other areas such as luminaire supports, impact attenuation devices, etc.

The success of this research, as evidenced by the rapid and extensive implementation of results, was not the work of one man, but many. The initial effort may be attributed mainly to the work of a few, but many quickly joined to make it a genuine team effort, where the researchers and the design engineers worked together, seeking a common goal. This is considered to be the most notable product of the research because it marked the beginning of truly cooperative research where the researcher seeks to understand the problems of the practicing design engineer and the engineer takes an active role in planning and guiding the research effort. Only in this manner can the greatest benefits be realized from research efforts, for research has little inventory value.

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INTRODUCTION

In the original development of the break-away sign support, the Texas Highway Department employed a cast-iron mechanical fuse as a connection at the "plastic hinge" joint on the support posts. The design of this cast-iron fuse was based on the net cross-sectional area with no regard to stress concentrations. After several wind load failures occurred in the field, an alternate design of a mechanical fuse fabricated from ASTM-A441 steel was proposed. This alternate fuse must resist static loads, and must become disengaged under impact loads caused by a collision. A full-scale crash test was conducted July 16, 1965 on a sign support containing a slotted steel fuse plate. This test indicated that the slotted plate would serve as a replacement for the cast-iron mechanical fuse.

The slotted plate mechanical fuse is essentially a friction connection when subjected to either static or dynamic loads. The strength of the connection is a function of the tensile force in the connecting bolts, and the coefficient of friction in the contact area between the slotted plate and flange of the support post.

The tensile force in the bolts for various design conditions was specified to conform with current specifications for ASTM A325 bolts.[1] The selection of slotted plate thickness was made in accordance with information contained in a research paper[2] concerning slip of bolted joints subjected to static loads. Texas Highway Department Standard SMD-8A, "Standard Roadside Plywood Guide Signs, Break-Away Type Posts," provides for a selection of support post size to meet varying requirements of sign dimensions, wind loads, etc. The post sizes currently employed are:

3I5.7
4I7.7
*6B8.5
6B12
6B15.5
*8WF17
8WF20
10WF21
*10WF25
12WF27

Post sizes marked with an asterisk were chosen as representing the entire set. A series of tensile tests was proposed to study the load-slip characteristics of five specimens of each of these three post sizes. The tensile tests are outlined in this report, and results and conclusions are presented.

REPORT ON STATIC TENSILE TEST OF SLOTTED PLATES

1. Apparatus

A. Loading Machine—Baldwin-Southwark-Emery 120,000 lb. cap. Constant Strain

B. Recorder & Linear Disp. Transducer
Honeywell Visicorder #1508
Sanborn Linear Differential Transformer #7DCDT-1000

C. Dividers & Scale
6″ Dividers & 12″ scale (0.01″ graduations)

D. Specimen Racks

E. Crescent Wrenches—2 ea. 14″, 1 ea. 10″

F. Ladder—8 ft., step

G. Wooden Blocks—1″ × 1″ × 6″—2 ea.

H. Adapters—Specimen to Tensile Stud—2 ea. for ea. size specimen

I. Studs—Adapter to Spherical Nut—2 ea.

2. Specimens (See Figure 1 and Table 1)

	Series
A. 6B8.5 with ⅝″ bolt dia. & ⅜″ plate thick.—5 ea.	(A & B)
B. 8WF17 with ⅞″ bolt dia. & ½″ plate thick.—10 ea.	(A, B & C)
C. 10WF25 with 1″ bolt dia. & ¾″ plate thick.—5 ea.	(5A & 2B)
10WF25 with 1″ bolt dia. & ⅝″ plate thick.—1 ea.	(B)
10WF25 with 1″ bolt dia. & ⅜″ plate thick.—1 ea.	(B)

3. Procedure

Three sizes of galvanized "I" beams (6B8.5, 8WF17, 10WF25), were split along their longitudinal axes to produce two "T" sections. Each "T" section, a full flange and half a web, was cut to length and drilled as shown in Figure 2. Each specimen consisted of two "T" sections bolted together with a slotted plate of the corresponding size. During assembly, the nuts were turned by wrench until snug, then marked to indicate the angle of rotation encountered by further tightening. After marking, the nuts were turned one-half to three-quarters turn to yield the bolts in tension. This ensured that all the bolts of a given size would have approximately the same tensile stress.[1] There were five specimens for each beam size.

A. *Series A*

The series A tests, conducted after the initial assembly of the specimens, simulated a wind load failure of a support that had neither encountered a collision nor been exposed to the weather.

The loading machine was made ready, and specimen number 1-8WF17 was mounted with the plate slots opening upward. The displacement transducer was calibrated and mounted, and the recorder made ready. The clearance between the bottom jaw and the sensitive platen was taken up with the spherical nut, and the loading machine dial set to zero.

A tensile load was applied by opening the micrometer valve to position ten. The valve setting was not changed during the test to ensure a constant rate of load application. The load trace on the oscillograph chart

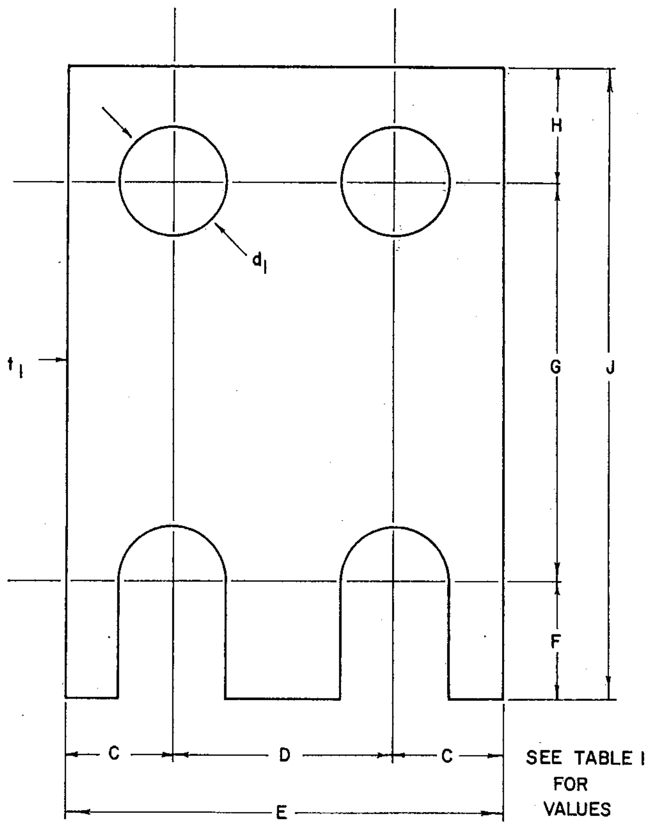

Figure 1. Fuse plate specimen.

TABLE 1. FUSE PLATE SPECIMENS
NOTE: See Figure 1 for nomenclature)

Post Size	Specimen Number	Test Series	Bolt Size	C	C	E	F	G	H	J	d_1	t_1
6B8.5	1-5	A&B	⅝″	⅞″	2¼″	4″	⅝″	2¾″	1″	4⅜″	11/16″	⅜″
8WF17	1-5	A&B	⅞″	1¼″	2¾″	5¼″	⅞″	3¼″	1¼″	5⅜″	15/16″	½″
	1-2	A&B	1″	1½″	2¾″	5¾″	1″	3¼″	1¼″	5½″	1 1/16″	¾″
10WF25	3-5	A	1″	1½″	2¾″	5¾″	1″	3¼″	1¼″	5½″	1 1/16″	¾″
	4	B	1″	1½″	2¾″	5¾″	1″	3¼″	1¼″	5½″	1 1/16″	⅝″
	5	B	1″	1½″	2¾″	5¾″	1″	3¼″	1¼″	5½″	1 1/16″	⅜″

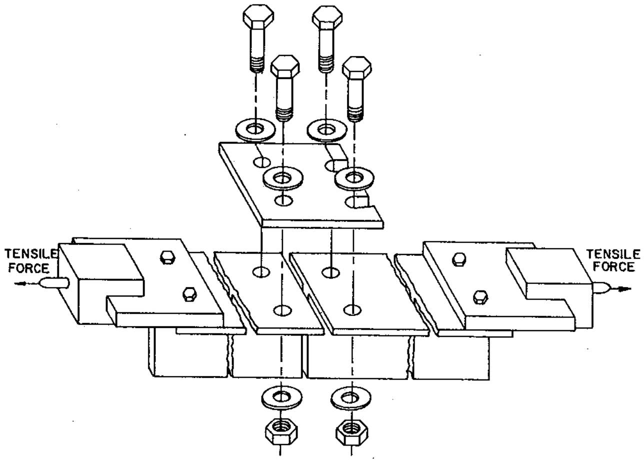

Figure 2. Test fixture for tensile test of slotted steel fuse plate.

was momentarily interrupted at increments of one thousand pounds and at the maximum load by the loading machine operator pressing an electrical push button switch. The recorder operator would then write the amount of load on the chart at the load trace interruption. When the load dropped below five hundred pounds, the loading machine micrometer valve was closed, the specimen separated by hand and removed from the loading machine.

Specimen number 2-8WF17 was mounted in the same manner as number 1-8WF17. The left edge of the flange (when facing the flange) was punch-marked on each side of the saw cut. The marks were spaced two inches apart. A pair of dividers was set to the punch-mark separation, measured on the one hundredth inch increment scale, and the separation distance recorded. The load was applied by opening the micrometer valve to position fifteen. The punch-mark separation was measured and recorded at one-thousand-pound increments and at maximum load while data were simultaneously recorded on the oscillograph recorder.

B. *Series B*

The series B tests were conducted after all the series A tests had been run and the specimens had been reassmbled using the same Tees, bolts, and plates. Two exceptions were specimen numbers 4 and 5—10WF25, which had a 5/8 inch and 3/8 inch plate, respectively, for the series B tests. These tests simulated a wind load failure after one collision experience of an unweathered support. All series B tests were run using both data recording systems, except for the 10WF25 tests, where only the punch-mark/divider system was used.

C. *Series C*

The series C tests, using five new 8WF17 specimens, were run to determine the effects of weathering on a fuse with no external loads applied during exposure. In April of 1966, this set of five newly assembled specimens was placed on the roof of a building at the TTI Safety Proving Grounds to weather. In April of 1967, these specimens were removed and tested in the same manner as series A and B except only the punch-mark/divider system was used to measure slip.

4. Data Reduction

The fuse plate resistance can be expressed as

$$F = mn\ f(s) N'$$

where

m = number of bolts crossing the slip plane
n = number of friction faces per bolt
f(s) = coefficient of friction
N' = load in the bolt, in this case assumed to be at proof load

with m = 2 and n = 2,

$$F = 4f(s) N'$$

or

$$f(s) = \frac{F}{4N'}$$

For any value of slip, s, the applied load is known, yielding the apparent coefficient of friction for that slip.[3]

The variation of average maximum load between series A and B and between series A and C was calculated from the following formula:

$$\%\ \text{variation} = 100 \times \left[\frac{(\text{Load B or C}) - (\text{Load A})}{\text{Load A}}\right]$$

Likewise, the average slip at average maximum load between series A and B and between series A and C was calculated from the following formula:

$$\%\ \text{variation} = 100 \times \left[\frac{(\text{Slip B or C}) - (\text{Slip A})}{\text{Slip A}}\right]$$

5. Results

A. *All tests*

Separation of the "T" sections began well before maximum load was reached, although most of the sep-

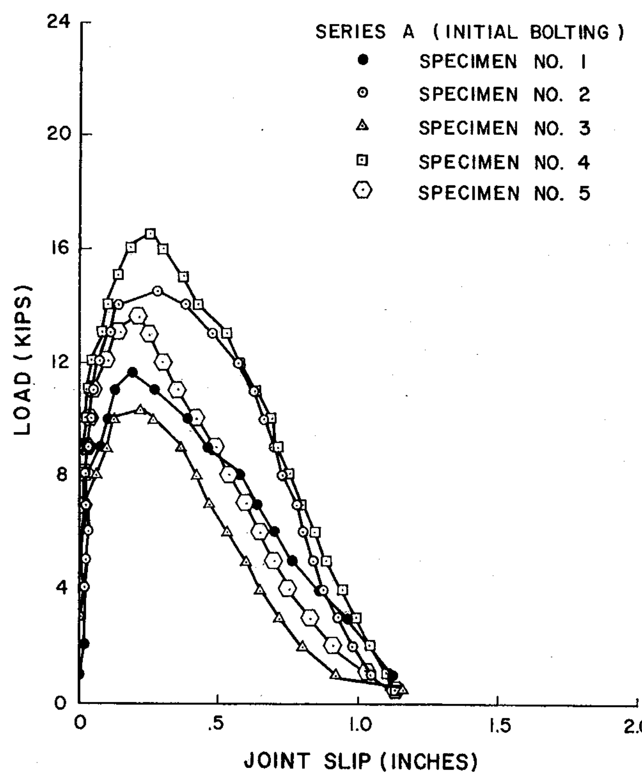

Figure 3. Slotted plate tensile tests (6 B 8.5).

TABLE 2. SUMMARY OF TEST DATA

Post Size	Series	Specimen Number	Maximum Load (kips)	Slip at Maximum Load (in)	Coefficient of Friction
6B8.5	A	1	11.65	0.19	0.1517
6B8.5	A	2	14.50	0.28	0.1888
6B8.5	A	3	10.35	0.22	0.1348
6B8.5	A	4	16.50	0.25	0.2148
6B8.5	A	5	13.60	0.21	0.1770
6B8.5	B	1	14.25	0.20	0.1855
6B8.5	B	2	16.60	0.25	0.2216
6B8.5	B	3	17.20	0.27	0.2240
6B8.5	B	4	22.50	0.21	0.2930
6B8.5	B	5	15.50	0.20	0.2018
8WF17	A	1	38.00	0.25	0.2635
8WF17	A	2	38.15	0.19	0.2646
8WF17	A	3	36.40	0.12	0.2524
8WF17	A	4	40.15	0.26	0.2784
8WF17	A	5	36.30	0.31	0.2517
8WF17	B	1	44.35	0.17	0.3076
8WF17	B	2	51.20	0.26	0.3550
8WF17	B	3	46.60	0.24	0.3232
8WF17	B	4	50.20	0.22	0.3481
8WF17	B	5	49.95	0.21	0.3464
8WF17	C	1	35.80	0.125	0.2483
8WF17	C	2	46.00	0.156	0.3190
8WF17	C	3	43.00	0.250	0.2982
8WF17	C	4	42.50	0.203	0.2947
8WF17	C	5	41.90	0.313	0.2906
10WF25	A	1	34.15	0.50	0.1807
10WF25	A	2	33.20	0.32	0.1757
10WF25	A	3	33.65	0.78	0.1780
10WF25	A	4	36.95	0.42	0.1955
10WF25	A	5	31.30	0.63	0.1656
10WF25	B	1	47.10	0.22	0.2492
10WF25	B	2	46.70	0.20	0.2471
10WF25 ⅝" PL	B	4	48.30	0.34	0.2556
10WF25 ⅜" PL	B	5	40.70	0.24	0.2153

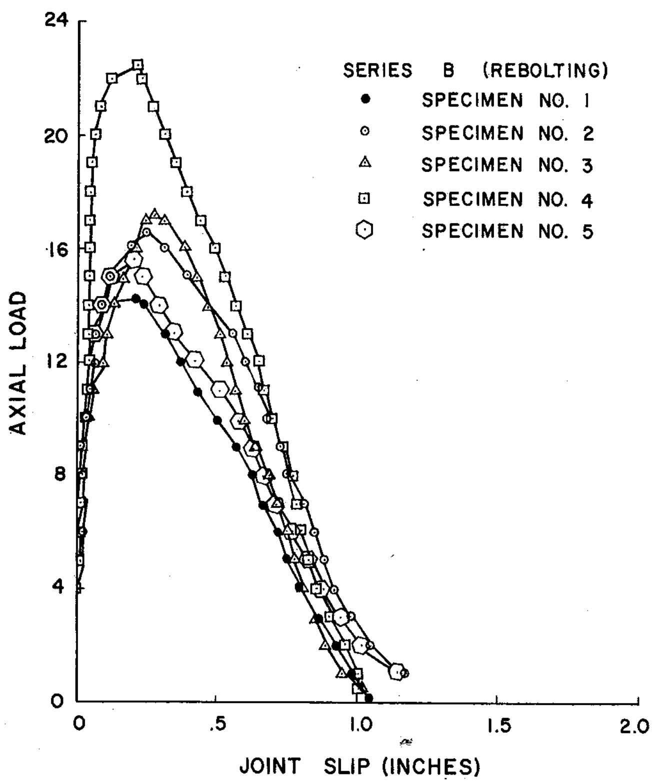

Figure 4. Slotted plate tensile tests (6 B 8.5).

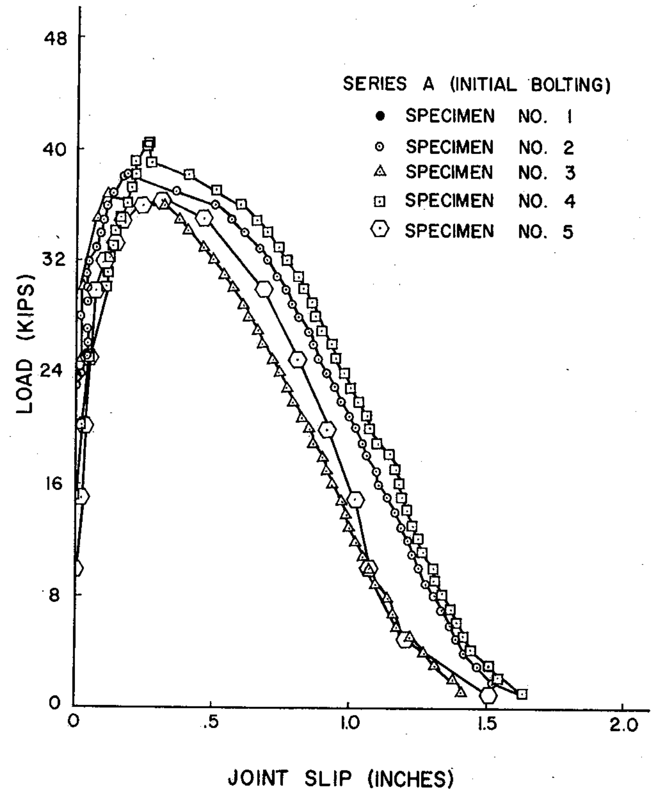

Figure 5. Slotted plate tensile tests (8 WF 17).

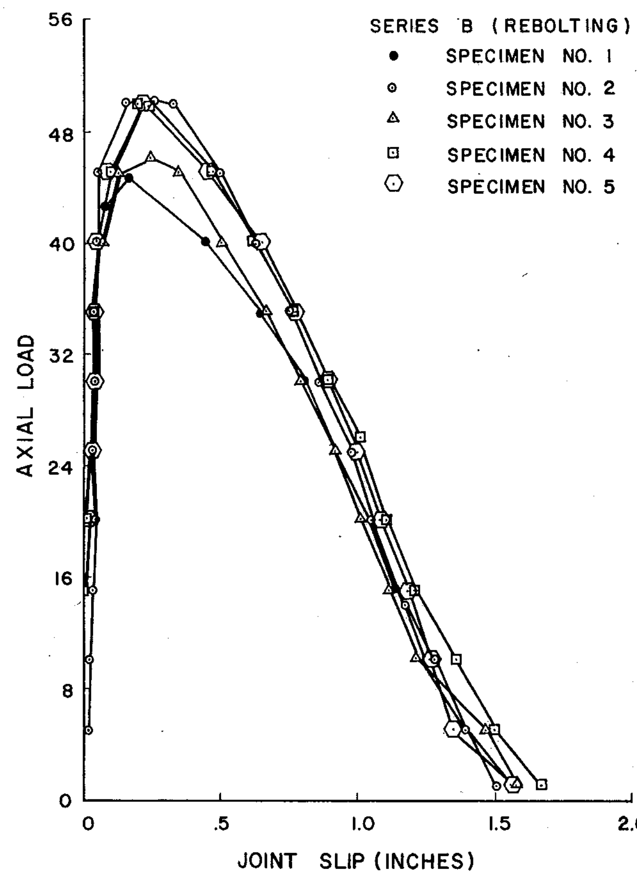

Figure 6. Slotted plate tensile tests (8 WF 17).

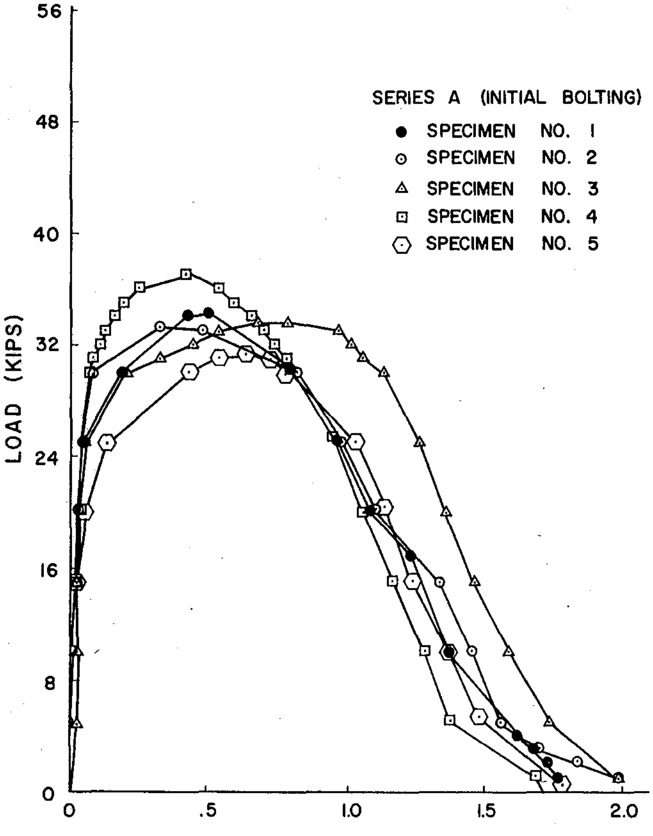

Figure 7. Slotted plate tensile tests (10 WF 25).

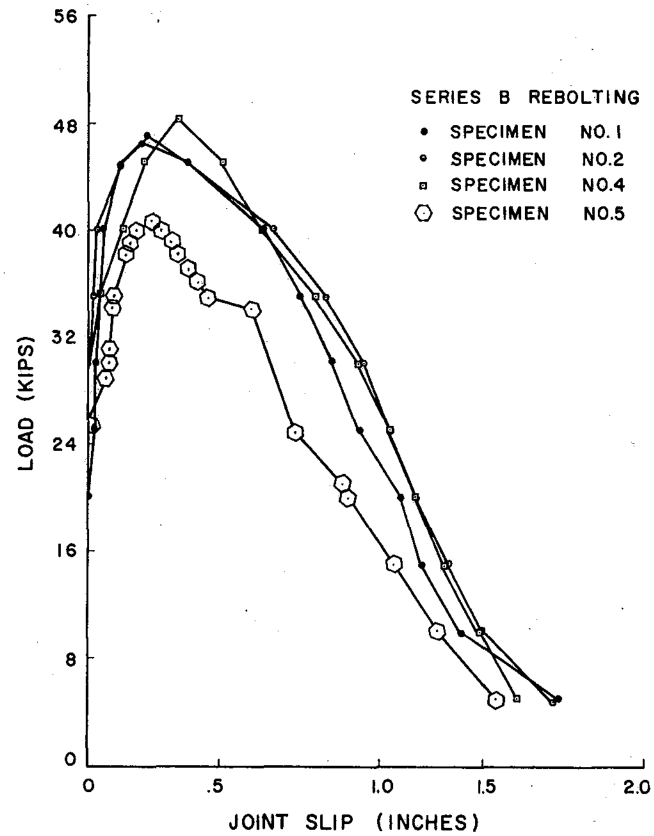

Figure 8. Slotted plate tensile tests (10 WF 25).

aration occurred after maximum load was reached (see Figures 3, 4, 5, 6, 7, 8, and 12).

After separation, the contact surfaces were galled. The bolt threads had indented the bolt hole surfaces and the bolt holes were elongated on both the "T" sections and the fuse plate.

B. *Comparison of Series A and B*

Each of the reassembled joints (series B) required a higher maximum load than for initial assembly (series A) (see Table 2). The average maximum load was from 28.5% to 38.6% higher between series A and B.

Specimens 4 and 5—10WF25—series B, showed increases of 42.7% and 20.2%, respectively, between series A and B (see Table 3). These two specimens, however, had new fuse plates of $\frac{5}{8}$ inch and $\frac{3}{8}$ inch thicknesses, respectively, instead of the original $\frac{3}{4}$ inch.

The bolts, nuts and washers were checked for hardness after the series A & B tests were run to see if they met A325 specifications. The bolts and washers were within specification, but the nuts were much too soft. (See Table 4.)

As a result, the bolts were not yielded in tension and the maximum loads were somewhat lower than the design loads.

TABLE 3. SUMMARY OF AVERAGES OF TEST DATA

Size	Series	Average Maximum Load (kips)	Average Slip At Average Maximum Load (in.)	Average Coefficient of Friction	Variation from Series A: Average Maximum Load %	Variation from Series A: Average Slip At Average Maximum Load %
6B8.5	A	13.32	0.23	0.173		
	B	17.21	0.226	0.224	+29.2	− 1.3
8WF17	A	37.80	0.226	0.262		
	B	48.56	0.220	0.337	+28.5	− 2.7
	C	41.82	0.227	0.290	+10.6	+ 0.44
10WF25	A	33.85	0.530	0.179		
	B	46.90	0.210	0.248	+38.6	−60.4
	B*	48.30	0.340	0.256	+42.7	−35.8
	B**	40.70	0.240	0.215	+20.2	−54.7

*$\frac{5}{8}$ Plate
**$\frac{3}{8}$ Plate

TABLE 4. ROCKWELL HARDNESS OF RANDOM SAMPLE OF FASTENER ASSEMBLY USED ON SLOTTED PLATE

Description	⅝″	⅞″	1″
Bolt	36 R_C	28 R_C	25 R_C
Nut	11-7 R_C (69 R_B)	11-7 R_C (68 R_B)	9 R_C (58 R_B)
Washers:			
No. 1	31 R_C	37 R_C	32 R_C
No. 2	34 R_C	17-23 R_C	36 R_C
No. 3	37 R_C	27 R_C	38 R_C

The coefficient of friction values were calculated using bolt load values from "turn of nut"[1] specifications. Although these bolt load values are higher than the actual bolt loads, they were used because actual values were unavailable. (See Table 3.) Figures 9, 10, and 11 show the upper and lower bound curves for the calculated values of the coefficient of friction.

C. *Comparison of Series A and C*

The average maximum load of series C was 10.6% higher than series A, while the average slip at average maximum load was virtually the same with a 0.44% increase. (See Table 3 and Figure 12.)

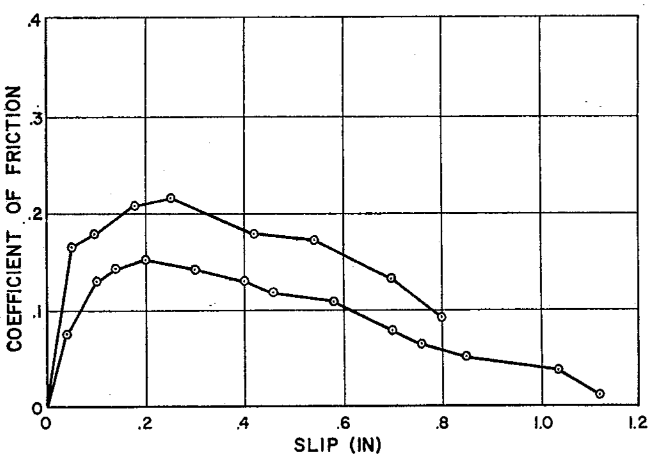

Figure 9. Coefficient of friction vs. slip (6 B 8.5).

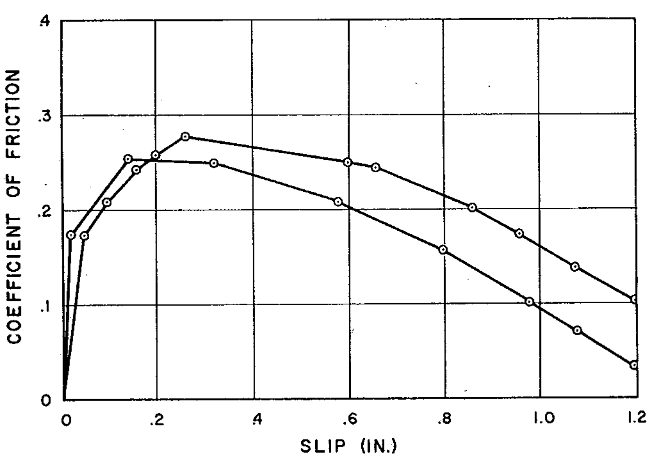

Figure 10. Coefficient of friction vs. slip (8 WF 17).

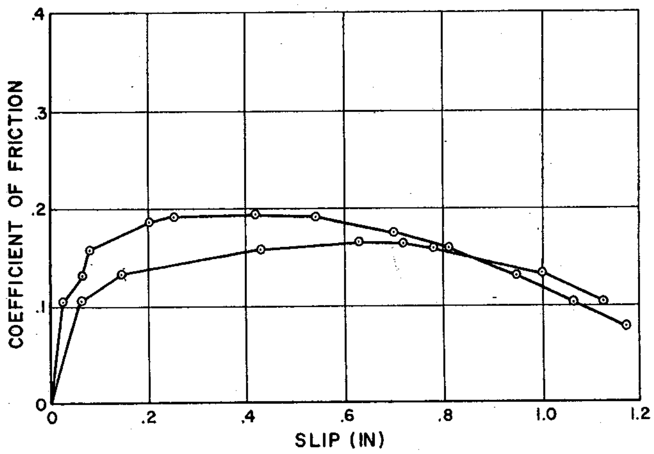

Figure 11. Coefficient of friction vs. slip (10 WF 25).

6. *Conclusions*

The series A and B tests indicate that, upon re-erection, a break-away sign support has a greater resistance to wind loads, i.e., reusing a support post does not diminish its wind load capacity.

The series C tests show that weathering has no detrimental effect on the fuse.

7. *Recommendations*

Activation of the fuse during a wind load failure or a collision event involves tensile and flexure loads on the fuse plate. A series of tests should be run with this type loading to accurately determine the minimum plate thickness and bolt diameter necessary for adequate wind load capacity combined with proper collision performance.

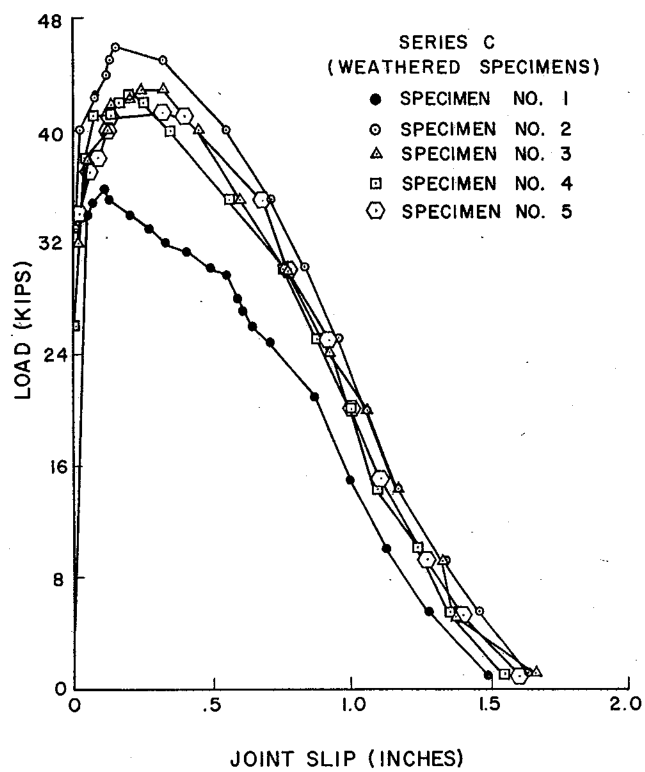

Figure 12. Slotted plate tensile tests (8 WF 17).

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2. "Slip of Joints Under Static Loads," R. A. Hechtman, D. R. Young, A. G. Chin, and E. R. Sanikko, Transaction of the American Society of Civil Engineers, Volume 120, 1955, pp. 1335-1352.

3. "Highway Sign Support Structures, Break-Away Roadside Sign Support Structures," Volume 1, July, 1967, Chapter 4, pp. 4:32-4:34.

GENERAL

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APPENDIX

SLOTTED STEEL FUSE PLATE TENSILE TEST

POST SIZE:	6B8.5	DATE:	12-20-65
BOLT DIAMETER:	⅝″	RECORDED BY:	Williams
PLATE THICKNESS:	⅜″	SERIES:	A

Specimen No. 1		Specimen No. 2		Specimen No. 3		Specimen No. 4		Specimen No. 5	
Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)
1	0.000	3	0.00	5	0.00	5	0.00	5	0.00
2	0.020	4	0.02	6	0.02	6	0.01	6	0.01
5	0.030	6	0.03	8	0.06	8	0.02	8	0.02
6	0.040	10	0.04	9	0.10	11	0.03	9	0.03
9	0.079	11	0.05	10	0.12	12	0.04	10	0.04
10	0.100	12	0.07	10.4	0.22	13	0.08	11	0.05
11	0.130	13	0.11	10	0.27	14	0.10	12	0.10
11.7	0.190	14	0.14	9	0.37	15	0.14	13	0.13
11	0.270	14.5	0.28	8	0.42	16	0.18	13.6	0.21
10	0.390	14	0.38	7	0.47	16.5	0.25	13	0.25
9	0.460	13	0.48	6	0.53	16	0.30	12	0.30
8	0.580	12	0.57	5	0.60	15	0.37	11	0.35
7	0.640	11	0.63	4	0.65	14	0.43	10	0.42
6	0.700	10	0.66	3	0.72	13	0.53	9	0.49
5	0.760	9	0.70	2	0.80	12	0.58	8	0.54
4	0.850	8	0.73	1	1.02	11	0.64	7	0.60
3	0.960	7	0.78	.5	1.16	10	0.69	6	0.65
2	1.030	6	0.80			9	0.71	5	0.70
1	1.130	5	0.84			8	0.75	4	0.75
.5	*	4	0.87			7	0.80	3	0.83
		3	0.93			6	0.84	2	0.91
		2	0.98			5	0.88	1	1.03
		1	1.05			4	0.94	.5	1.13
						3	0.99		
						2	1.04		
						1	1.10		
						.5	1.15		

*Specimen slipped apart.

SLOTTED STEEL FUSE PLATE TENSILE TEST

POST SIZE:	8WF17	DATE:	4-14-67
BOLT DIAMETER:	⅞″	RECORDED BY:	M. C. White
PLATE THICKNESS:	½″	SERIES:	C

Specimen No. 1		Specimen No. 2		Specimen No. 3		Specimen No. 4		Specimen No. 5	
Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)
10	.000	0	.000	0	.000	0	.000	0	.000
30	.016	33	.016	32	.031	26	.016	34	.031
32	.032	40	.031	38	.063	38	.047	37	.063
34	.063	42	.094	40	.125	41	.078	38	.094
35	.078	42.1	.094	41.9	.141	41.2	.140	40	.125
35.8	.125	44	.125	42.9	.219	42	.172	41	.141
35	.156	45	.141	43	.250	42.5	.203	41.9	.313
34	.219	46	.156	42		42	.266	41	.406
33	.281	45	.344	43	.313	40	.359	40	.469
32	.344	40	.563	40	.469	35	.578	35	.688
31	.438	35	.719	35	.625	30	.766	30	.781
30	.500	30	.844	30	.781	25	.891	25	.934
29	.563	25	.969	24	.934	20	1.016	20	
28	.594	20	1.063	20	1.063	15	1.109	15	1.156
27	.625	15	1.188	15	1.189	10	1.234	10	1.281
26	.656	10	1.344	10	1.313	5	1.359	5	1.406
25	.719	5	1.469	5	1.375	1	1.578	1	1.625
20	.875	1	1.656	1	1.688				
15	1.000								
10	1.125								
5	1.281								
1	1.500								

SLOTTED STEEL FUSE PLATE TENSILE TEST

POST SIZE: 10WF25
BOLT DIAMETER: 1″
PLATE THICKNESS: ¾″

DATE: 12-17-65
RECORDED BY: T. G. Williams
SERIES: A

Specimen No. 1		Specimen No. 2		Specimen No. 3		Specimen No. 4		Specimen No. 5	
Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)
15	.00	5	.00	15	.02	10	.00	10	.00
20	.03	10	.02	20	.03	15	.02	15	.02
25	.06	20	.03	25	.04	20	.03	20	.05
30	.18	25	.04	30	.20	25	.04	25	.13
34	.42	30	.08	31	.32	30	.07	30	.43
34.2	.50	33.2	.32	32	.44	31	.08	31	.54
30	.83	33	.48	33	.53	32	.11	31.3	.63
25	.97	30	.80	33.5	.67	33	.13	31	.72
20	1.10	25	.98	33.7	.78	34	.16	30	.78
15	1.23	20	1.11	33	.97	35	.19	25	1.03
10	1.37	15	1.24	32	1.01	36	.25	20	1.13
5	1.58	10	1.36	31	1.06	37	.42	15	1.23
4	1.63	5	1.57	30	1.13	36	.54	10	1.37
3	1.68	4	1.62	25	1.26	35	.59	5	1.49
2	1.73	3	1.70	20	1.36	34	.66	1	1.75
1	1.77	2	1.84	15	1.46	33	.70	.5	1.79
		1	1.99	10	1.59	32	.74		
				5	1.74	31	.78		
				1	1.99	30	.81		
						25	.95		
						20	1.06		
						15	1.17		
						10	1.29		
						5	1.38		
						1	1.69		

SLOTTED STEEL FUSE PLATE TENSILE TEST

POST SIZE: 10WF25
BOLT DIAMETER: 1″
PLATE THICKNESS: ¾″, ⅝″, ⅜″

DATE: 12-27-65
RECORDED BY: Whitson
SERIES: B

Specimen No. 1		Specimen No. 2		Specimen No. 3		Specimen No. 4		Specimen No. 5	
Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)
(¾″ thick)		(¾″ thick)		NO SLIP DATA		(⅝″ thick)		(⅜″ thick)	
20	0.00	30	0.00	RECORDED ON		30	0.00	25	0.00
25	0.02	35	0.02			35	0.04	29	0.06
35	0.04	40	0.04	SPECIMEN NO.		40	0.13	30	0.08
40	0.06	45	0.12			45	0.22	34	0.09
45	0.12	46.7	0.20	3		48.3	0.34	35	0.10
47.1	0.22	45	0.38			45	0.51	38	0.14
45	0.38	40	0.70			40	0.66	39	0.16
40	0.66	35	0.90			35	0.86	40	0.18
35	0.80	30	1.04			30	1.02	40.7	0.24
30	0.92	25	1.14			25	1.14	40	0.28
25	1.02	20	1.24			20	1.24	39	0.32
20	1.13	15	1.36			15	1.34	38	0.34
15	1.26	10	1.50			10	1.48	37	0.38
10	1.41	5	1.76			5	1.62	36	0.42
5	1.78							35	0.46
								30	0.62
								25	0.78
								21	0.96
								20	0.98
								15	1.16
								10	1.32
								5	1.54

SLOTTED STEEL FUSE PLATE TENSILE TEST

POST SIZE: 6B8.5
BOLT DIAMETER: ⅝″
PLATE THICKNESS: ⅜″

DATE: 12-22-65
RECORDED BY: T. G. Williams
SERIES: B

Specimen No. 1		Specimen No. 2		Specimen No. 3		Specimen No. 4		Specimen No. 5	
Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)
6	0.00	5	0.00	7	0.00	4	0.00	6	0.00
7	0.02	6	0.01	8	0.02	5	0.02	7	0.02
10	0.03	7	0.02	10	0.03	8	0.03	10	0.03
11	0.04	9	0.03	11	0.04	12	0.04	12	0.04
12	0.05	10	0.04	12	0.09	19	0.05	13	0.06
13	0.07	13	0.07	13	0.10	20	0.06	14	0.07
14	0.10	14	0.09	14	0.13	21	0.08	15	0.12
14.3	0.20	15	0.13	15	0.16	22	0.12	15.5	0.20
14	0.23	16	0.19	16	0.20	22.5	0.21	15	0.23
13	0.31	16.6	0.25	17	0.24	22	0.23	14	0.29
12	0.37	16	0.31	17.2	0.27	21	0.27	13	0.34
11	0.43	15	0.39	17	0.31	20	0.31	12	0.42
10	0.50	14	0.47	16	0.38	19	0.35	11	0.51
9	0.57	13	0.55	15	0.43	18	0.39	10	0.58
8	0.63	12	0.60	14	0.47	17	0.44	9	0.64
7	0.66	11	0.65	13	0.51	16	0.49	8	0.67
6	0.72	10	0.69	12	0.54	15	0.53	7	0.72
5	0.75	9	0.74	11	0.57	14	0.57	6	0.77
4	0.80	8	0.77	10	0.60	13	0.61	5	0.82
3	0.86	7	0.81	9	0.64	12	0.65	4	0.88
2	0.92	6	0.85	8	0.68	11	0.67	3	0.94
1	0.99	5	0.88	7	0.71	10	0.70	2	1.02
.5	1.04	4	0.92	6	0.75	9	0.73	1	1.15
		3	0.98	5	0.78	8	0.75		
		2	1.05	4	0.81	7	0.78		
		1	1.17	3	0.85	6	0.80		
				2	0.89	5	0.83		
				1	0.95	4	0.86		
				.5	1.01	3	0.91		
						2	0.96		
						1	1.01		

SLOTTED STEEL FUSE PLATE TENSILE TEST

POST SIZE:	8WF17	DATE:	12-17-65
BOLT DIAMETER:	⅞″	RECORDED BY:	T. G. Williams
PLATE THICKNESS:	½″	SERIES:	A

Specimen* No. 2				Specimen No. 3		Specimen No. 4				Specimen No. 5	
Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)
24	0.00	24	0.90	20	.00	15	.00	11	1.27	10	.0
25	0.02	23	0.93	25	.01	20	.02	10	1.30	15	.02
32	0.03	22	0.95	30	.02	25	.05	9	1.31	20	.03
33	0.05	21	0.98	35	.08	30	.11	8	1.34	25	.04
34	0.07	20	1.00	36.4	.12	32	.12	7	1.37	30	.07
35	0.08	19	1.03	36	.32	33	.13	6	1.39	32	.11
36	0.09	18	1.04	35	.38	34	.14	5	1.42	33	.14
37	0.12	17	1.08	34	.42	35	.16	4	1.44	34	.16
38	0.15	16	1.09	33	.47	36	.19	3	1.51	35	.17
38.2	0.17	15	1.12	32	.51	37	.20	2	1.54	36	.24
38	0.19	14	1.15	31	.55	38	.21	1	1.64	36.3	.31
37	0.35	13	1.17	30	.58	40	.25	.5	1.71	35	.47
36	0.49	12	1.20	29	.62	40.2	.26			30	.69
35	0.55	11	1.22	28	.64	39	.27			25	.81
34	0.60	10	1.24	27	.67	38	.41			20	.92
33	0.65	9	1.26	26	.69	37	.51			15	1.02
32	0.68	8	1.29	25	.73	36	.60			10	1.07
31	0.72	7	1.32	24	.75	35	.66			5	1.20
30	0.75	6	1.35	23	.78	34	.70			1	1.51
29	0.77	5	1.38	22	.80	33	.74				
28	0.80	4	1.41	21	.83	32	.77				
27	0.83	3	1.45	20	.86	31	.81				
26	0.85	2	1.50	19	.87	30	.83				
25	0.87	1	1.61	18	.90	29	.86				
				17	.92	28	.88				
				16	.94	27	.90				
				15	.97	26	.94				
				14	.99	25	.95				
				13	1.00	24	.98				
				12	1.03	23	1.00				
				11	1.05	22	1.03				
				10	1.07	21	1.06				
				9	1.10	20	1.07				
				8	1.14	19	1.10				
				7	1.16	18	1.15				
				6	1.18	17	1.17				
				5	1.22	16	1.18				
				4	1.27	15	1.19				
				3	1.31	14	1.21				
				2	1.38	13	1.23				
				1	1.42	12	1.25				

*No slip data recorded on Specimen No. 1.

SLOTTED STEEL FUSE PLATE TENSILE TEST

POST SIZE:	8WF17	DATE:	12-21-65
BOLT DIAMETER:	⅞″	RECORDED BY:	T. G. Williams
PLATE THICKNESS:	½″	SERIES:	B

Specimen No. 1		Specimen No. 2		Specimen No. 3		Specimen No. 4		Specimen No. 5	
Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)	Load (kips)	Slip (in)
5	0.00	5	0.00	20	0.00	15	0.00	20	0.00
10	0.01	10	0.02	25	0.02	20	0.02	25	0.02
15	0.02	15	0.03	30	0.03	25	0.03	30	0.03
20	0.03	20	0.04	35	0.04	30	0.04	40	[illegible]
35	0.04	40	0.05	40	0.06	40	0.05	45	
40	0.05	50	0.15	45	0.12	45	0.10	50	
42.5	0.07	51.2	0.26	46.6	0.24	50	0.20	45	
44.4	0.17	50	0.32	45	0.34	50.2	0.22	40	
40	0.44	45	0.49	40	0.50	50	0.24	35	
35	0.64	40	0.63	35	0.66	45	0.46	30	0.89
30	0.80	35	0.75	30	0.79	40	0.61	25	0.99
25	0.92	30	0.86	25	0.91	35	0.75	20	1.08
20	1.03	25	0.97	20	0.01	30	0.88	15	1.18
15	1.14	20	1.05	15	1.11	25	1.00	10	1.26
10	1.24	15	1.17	10	1.21	20	1.10	5	1.34
5	1.38	10	1.29	5	1.36	15	1.20	1	1.56
1	1.55	5	1.39	1	1.57	10	1.35		
		1	1.50			5	1.49		
						1	1.66		