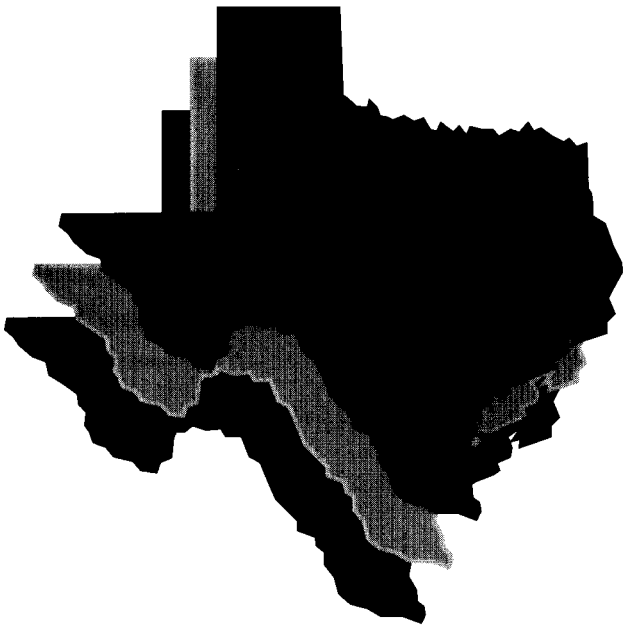
TEST PROGRAM FOR BREAKAWAY SIGNS

DHT–29



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16. Abstract

In 1990 and 1991, the Lubbock District, prompted by an FHWA inspection, conducted a series of tests to determine whether current specified torque settings for bolts on breakaway signs were appropriate. Too high a torque could impair the effectiveness of the beakaway mounting, while too low a torque could result in loosening of the bolts, increasing the possibility of the sign blowing down. The test procedure evaluated the effects of three factors: bolt torque, sign area, and wind velocity. The test results were inconsistent, partly due to the lack of accurate wind velocity data at specific sign locations. Additional studies should be conducted in a controlled environment to obtain more conclusive results. Meanwhile, bolts should be torqued to the specified settings and recurring sign failures dealt with on an individual basis.

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TEST PROGRAM FOR BREAKAWAY SIGNS

by
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Research Report DHT-29

conducted by
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TABLE OF CONTENTS

DISCLAIMER STATEMENT

The material in this report is experimental in nature and is published for informational purposes only. Any discrepancies with official views or policies of the Texas Department of Transportation (TxDOT) should be discussed with the appropriate Austin division prior to implementation of the procedures or results. The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

BREAKAWAY SIGNS

During December 1989, an FHWA field inspection of a five mile section of IH 27 found that most bolts tested on breakaway signs were set at a higher torque than specified by sign mounting standards. District maintenance personnel contended that the higher torques were necessary in order to prevent the signs from "walking off" the stub posts during wind storms. The district agreed to a "Test Program" which involved torquing the bolts on slip plates to various inch/pound (in-lb.) settings. The signs were then monitored and reset as necessary during the spring wind storms.

The test periods chosen were January through May of 1990, and 1991. Three maintenance sections were part of the test in both years. The sections were Lubbock NE (08), Plainview (13), and Littlefield (07).

Each section chose signs to be used in the test program. Each sign chosen was torqued to a specified in-lb. setting. The signs were then monitored on a periodic basis and reset as necessary. Data recorded for the signs in each section are shown in Tables 1 through 6. The numerals shown in columns under time periods and wind velocities indicate the number of nuts loosened during the time period. Thus 0 would mean that all nuts were at the correct torque while a 2 would mean that two nuts had to be retorqued to the proper setting. Two tables are shown for each section and year. The first table shows all data based upon the section number system. The second table is prioritized first by the beam or pipe size and second by the area of the sign. Following each set of tables are comments.

The comments under the data tables for each section present a brief comparison of torque failures among a group of signs of like size and comparable wind conditions when the bolt torque securing the sign post to the sign stub is varied. The test results were measured by the number of bolts loosened during the observation period. In this report, one loosened bolt will be referred to as one failure. Assuming that the sign areas and wind velocities are constant with only the bolt torques being varied, the results measured by the number of failures during an observation period are varied and contradictory. Generally, it would be assumed that with wind speed and sign area being constant, as bolt torque is increased failures would decrease. This did not always prove to be true. Reasonably, it would be assumed that with sign area and bolt torques constant, failures would increase as wind speeds increased. Again the data did not always support the assumption. Finally, it would be assumed that with the wind speed and the bolt torque constant, an increase in sign area would increase failures. The test data generally tended to confirm this assumption.

TEST SECTION DISCUSSION

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity									Beam or Pipe Size (in.)
				1-4/1-12 Normal	1-12/1-23 20-30	1-23/2-1 30-40	2-1/2-13 30-40	2-13/3-5 35-40	3-1/3-15 40-45	3-15/4-5 20-25	4-5/4-15 30-40	4-25/6-1 30-40	
07-A-1	200	200	30	0	1	0	0	0	0	0	0	0	4
07-A-2	200	300	30	0	0	0	0	0	0	0	0	0	4
07-A-3	200	400	30	0	0	0	0	0	0	0	0	0	4
07-B-1	450	700	123.5	0	0	0	0	1	0	0	0	1	6
07-B-2	450	800	123.5	3	2	1	1	0	0	1	0	0	6
07-B-3	450	900	123.5	0	0	0	0	0	1	0	0	0	6
07-C-1	750	1000	156	2	1	0	0	1	1	0	0	2	10
07-C-2	750	1100	156	0	2	1	0	0	0	0	0	0	10
07-C-3	750	1200	160	0	0	0	0	0	0	0	0	0	10

TABLE 1: 1990 LITTLEFIELD DATA

LITTLEFIELD — 1990

Signs 7-A-1, 2, and 3 were mounted on S4 × 7.7 "I" beam posts. The post is mounted to the stub with 1/2 inch bolts. The specification torque for 1/2 inch bolts is 200 in-lbs. Bolts holding the test signs were set to torques of 200, 300, and 400 in-lbs. Only one bolt, set at a torque of 200 in-lbs, required resetting during the course of the test. Interestingly, the one loosened bolt did not occur during a period of maximum recorded wind speed.

Signs 7-B-1, 2, and 3 were mounted on W6 × 12 "I" beam posts. The post is mounted to the stub with 5/8 inch bolts. The specification torque for 5/8 inch bolts is 450 in-lbs. Bolts holding the test signs were set to torques of 700, 800, and 900 in-lbs. Sign 7-B-1, torqued at 700 in-lbs, had two failures; sign 7-B-2, set at 800 in-lbs, had eight failures; and sign 7-B-3, set at 900 in-lbs, had one failure. Thus the sign with the most failures was torqued at 800 in-lbs and the three and two failures came at a time of indicated lower wind speeds.

Signs 7-C-1, 2, and 3 were mounted on W10 × 22 "I" beam posts. The post is mounted to the stub with 3/4 inch bolts. The specification torque for 3/4 inch bolts is 750 in-lbs. Bolts holding the test signs were set to torques of 1,000, 1,100, and 1,200 in-lbs. Sign 7-C-1, torqued at 1,000 in-lbs, had seven failures during the test period. Sign 7-C-2 at 1,100 had three failures and sign 7-C-3, set at 1,200 in-lbs, had no failures. The bolts torqued at 1,000 in-lbs had two failures at normal wind speed and one when the wind speed was recorded at 20-30 miles per hour. The bolts torqued at 1,100 in-lbs had two failures when the wind speed was recorded at 20-30 mph.

Thus five failures are recorded during periods of lower wind speeds.

LITTLEFIELD — 1991

TABLE 2A: 1991 LITTLEFIELD DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity					Beam or Pipe Size (in.)
				1-8/1-24 20-30	1-24/2-22 30-40	2-22/3-2 740-50	3-27/4-22 30-40	4-22/6-1 040-50	
07-1	200	200	30	2	0	1	1	2	4
07-2	200	250	30	2	0	1	0	0	4
07-3	200	300	30	2	0	1	1	0	4
07-4	450	450	6	0	0	0	0	0	3 P
07-5	450	500	6	0	0	0	0	0	3 P
07-6	450	550	6	0	0	0	0	0	3 P
07-7	450	450	5	0	0	0	0	0	3 p
07-8	450	500	5	0	0	0	0	0	3 P
07-9	450	550	5	0	0	0	0	0	3 P

TABLE 2B: 1991 LITTLEFIELD DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity					Beam or Pipe Size (in.)
				1-8/1-24 20-30	1-24/2-22 30-40	2-22/3-2 740-50	3-27/4-22 30-40	4-22/6-1 040-50	
07-7	450	450	5	0	0	0	0	0	3 P
07-8	450	500	5	0	0	0	0	0	3 P
07-9	450	550	5	0	0	0	0	0	3 P
07-4	450	450	6	0	0	0	0	0	3 P
07-5	450	500	6	0	0	0	0	0	3 P
07-6	450	550	6	0	0	0	0	0	3 P
07-1	200	200	30	2	0	1	1	2	4
07-2	200	250	30	2	0	1	0	0	4
07-3	200	300	30	2	0	1	1	0	4

Signs 7-7, 7-8, 7-9, 7-4, 7-5, and 7-6 were mounted on three-inch pipes. The posts are mounted to the stubs with 5/8 inch bolts. The specification torque for 5/8 inch bolts is 450 in-lbs. Signs 7-7 and 7-4 were set at a torque of 450 in-lbs. Signs 7-8 and 7-5 were set at a torque of 500 in-lbs, and signs 7-9 and 7-6 were set at a torque of 550 in-lbs. There were no failures in any of the signs. The sign areas are uniform and small.

Signs 7-1, 7-2, and 7-3 were mounted on S4 × 7.7 "I" beam posts. The posts are mounted to the stubs with 1/2 inch bolts. The specification torque for 1/2 inch bolts is 200 in-lbs. Sign 7-1, torqued to 200 in-lbs, suffered six failures during the test period. Sign 7-2, torqued to 250 in-lbs, suffered three failures and and sign 7-3 torqued to 300 in-lbs suffered four failures.

LUBBOCK N.E. — 1990

TABLE 3A: 1990 LUBBOCK N.E. DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity									Beam or Pipe Size (in.)
				1-18/1-30 35	1-30/2-16 41	2-16/3-5 33	3-5/3-19 46	3-19/4-2 28	4-2/4-24 41	4-24/5-14 33	5-14/5-30 32	5-30/6-7 26	
08-1	750	950	191	4	0	0	0	0	0	0	0	0	8
08-2	200	400	40	2	0	0	0	0	0	0	0	0	4
08-3	450	650	32	0	0	0	0	0	0	0	0	0	3 P
08-4	750	850	126	0	0	1	0	1	0	0	1	0	8
08-5	450	450	20	2	3	**							3 P
08-5	450	550	20			0	3	0	0	0	0	0	3 P
08-6	200	200	46	0	3	0	0	4	4	1	0	0	4
08-7	450	550	20	1	2	*	0	0	0	0	0	0	3 P
08-8	200	300	46	0	0	0	0	0	0	0	0	0	4
08-9	750	750	116	0	0	0	0	0	0	0	0	0	8

* Sign blew down 2-20-90 - reset to 550

**Sign blew down 2-13-90 - reset at 550

TABLE 3B: 1990 LUBBOCK N.E. DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity									Beam or Pipe Size (in.)
				1-18/1-30 35	1-30/2-16 41	2-16/3-5 33	3-5/3-19 46	3-19/4-2 28	4-2/4-24 41	4-24/5-14 33	5-14/5-30 32	5-30/6-7 26	
08-5	450	550	20			0	3	0	0	0	0	0	3 P
08-5	450	450	20	2	3	**							3 P
08-7	450	550	20	1	2	*	0	0	0	0	0	0	3 P
08-3	450	650	32	0	0	0	0	0	0	0	0	0	3 P
08-2	200	400	40	2	0	0	0	0	0	0	0	0	4
08-6	200	200	46	0	3	0	0	4	4	1	0	0	4
08-8	200	300	46	0	0	0	0	0	0	0	0	0	4
08-9	750	750	116	0	0	0	0	0	0	0	0	0	8
08-4	750	850	126	0	0	1	0	1	0	0	1	0	8
08-1	750	950	191	4	0	0	0	0	0	0	0	0	8

*Sign blew down 2-20-90 - reset to 550

**Sign blew down 2-13-90 - reset at 550

Signs 8-3, 5, and 7 were mounted on three inch pipes. The post is mounted to the stub with 5/8 inch bolts. The specification torque for 5/8 inch bolts is 450 in-lbs. Bolts holding the test signs were set to torques of 450, 550, and 650 in-lbs. Sign 8-5, torqued to 450 in-lbs, had five failures during the first month of the test period and finally blew down February 13, 1990. The sign was reset and torqued to 550 in-lbs for the remainder of the test period. The sign had three failures during the remainder of the test period. Sign 8-7 was torqued at 550 in-lbs and had three failures before the sign blew down February 20, 1990. The sign was reset with torque at 550 in-lbs and had no more failures during the test period. Sign 8-3 was set at a torque of 650 in-lbs and did not suffer a failure during the test period.

Signs 8-2, 6, and 8 were mounted on S4 × 7.7 "I" beam posts. The post is mounted to the stub with 1/2 inch bolts. The specification torque for 1/2 inch bolts is 200 in-lbs. Bolts holding the test signs were set to torques of 200, 300, and 400 in-lbs. Sign 8-6, torqued at 200 in-lbs, suffered 12 failures during the test period. Sign 8-8, torqued to 300 in-lbs, did not have a failure. Sign 8-2, torqued to 400 in-lbs, suffered one failure during the test period.

Signs 8-1, 4, and 9 were mounted on W8 × 21 "I" beam posts. The post is mounted to the stub with 3/4 inch bolts. The specification torque for 3/4 inch bolts is 750 in-lbs. Bolts holding the test signs were set to torques of 750, 850, and 950 in-lbs. Sign 8-9, torqued to 750 in-lbs, did not suffer a failure during the test period. Sign 8-4, torqued to 850 in-lbs, suffered three failures. Sign 8-1, torqued to 950 in-lbs, suffered four failures.

LUBBOCK N.E. — 1991

TABLE 4A: 1991 LUBBOCK N.E. DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity								Beam or Pipe Size (in.)
				1-19/1-28 31	1-28/2-8 28	2-8/2-21 28	2-21/3-11 45	3-11/3-27 40	3-27/4-15 36	4-15/5-2 32	5-2/6-11 41	
08-1	450	450	16	0	0	0	1	0	0	2	0	3 P
08-2	750	850	178	0	0	0	0	0	0	0	0	8
08-3	750	850	148	3	0	0	0	0	0	0	0	8
08-4	750	750	162	0	0	0	0	0	0	0	0	8
08-5	450	500	16	1	0	0	0	0	0	0	0	3 P
08-6	750	750	138	0	0	0	0	0	0	0	0	8
08-7	750	950	159	0	0	0	0	0	2	0	0	8
08-8	750	950	183	No Keeper Plate			0	3	2	0	0	3
08-9	450	550	16	0	0	0	0	0	0	0	0	3 P
08-10	450	450	41	0	0	0	1	1	0	0	2	3 P
08-11	450	500	41	1	0	0	0	2	0	2	0	3 P
08-12	450	550	41	0	0	0	0	3	0	1	0	3 P

TABLE 4B: 1991 LUBBOCK N.E. DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity								Beam or Pipe Size (in.)
				1-19/1-28 31	1-28/2-8 28	2-8/2-21 28	2-21/3-11 45	3-11/3-27 40	3-27/4-15 36	4-15/5-2 32	5-2/6-11 41	
08-1	450	450	16	0	0	0	1	0	0	2	0	3 P
08-5	450	500	16	1	0	0	0	0	0	0	0	3 P
08-9	450	550	16	0	0	0	0	0	0	0	0	3 P
08-10	450	450	41	0	0	0	1	1	0	0	2	3 P
08-11	450	500	41	1	0	0	0	2	0	2	0	3 P
08-12	450	550	41	0	0	0	0	3	0	1	0	3 P
08-6	750	750	138	0	0	0	0	0	0	0	0	8
08-3	750	850	148	3	0	0	0	0	0	0	0	8
08-7	750	950	159	0	0	0	0	0	2	0	0	8
08-4	750	750	162	0	0	0	0	0	0	0	0	8
08-2	750	850	178	0	0	0	0	0	0	0	0	8
08-8	750	950	183	No Keeper Plate			0	3	2	0	0	8

Signs 8-1, 8-5, 8-9, 8-10, 8-11, and 8-12 were mounted on three-inch pipes. The posts were mounted to the stubs with 5/8 inch bolts. The specification torque for 5/8 inch bolts is 450 in-lbs. Signs 8-1, 8-5, and 8-9 have relatively small sign area. Sign 8-1, torqued to 450 in-lbs, suffered three failures during the test period. Sign 8-5, torqued to 500 in-lbs, suffered one failure during the test period. Sign 8-9, torqued to 550 in-lbs, did not have a failure during the test period. Signs 8-10, 8-11, and 8-12 have a much larger sign area. Sign 8-10, torqued to 450 in-lbs, suffered four failures; sign 8-11, torqued to 500 in-lbs, suffered five failures; and sign 8-12, torqued to 550 in-lbs, suffered four failures during the test period.

Signs 8-6, 8-3, and 8-7 were mounted on W8 × 21 "I" beam posts. The posts were mounted to the stubs with 3/4 inch bolts. The specification torque for 3/4 inch bolts is 750 in-lbs. Sign 8-6, torqued to 750 in-lbs, did not have a failure during the test period. Sign 8-3, torqued to 850 in-lbs, suffered three failures. All three failures occurred during the same period and during moderately high winds. Sign 8-7, torqued to 950 in-lbs, suffered two failures. Both failures occurred during the same time period and during a period of moderately high winds.

Signs 8-4, 8-2, and 8-8 were mounted on W8 × 21 "I" beam posts. The posts were mounted to the stubs with 3/4 inch bolts. The specification torque for 3/4 inch bolts is 750 in-lbs. These three signs have a larger sign area than the preceding three. Sign 8-4, torqued to 750 in-lbs, did not suffer a failure during the test period. Sign 8-2, torqued to 850 in-lbs, did not have a failure. Sign 8-8, torqued to 950 in-lbs, suffered five failures during an abbreviated test period from February 21 through June 11, 1991.

PLAINVIEW — 1990

TABLE 5A: 1990 PLAINVIEW DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity				Beam or Pipe Size (in.)
				1-4/2-6 30	2-6/3-1 40	3-1/4-15 40	4-16/6-11 30-40	
13-1	200	200	36	0	6	0	0	4
13-2	450	450	93	1	2	0	0	6
13-3	450	450	32	0	2	0	1	3 P
13-4	450	800	91		0	0	0	6
13-5	200	300	48		2	0	4	4
13-6	450	800	32		1	0	2	3 P
13-7	450	900	70		0	0	0	6
13-8	450	650	16		0	0	0	3 P
13-9	450	950	172		0	0	1	8
13-A-1	450	550	32			0	1	3 P
13-A-2	450	750	32			0	1	3 P

TABLE 5B: 1990 PLAINVIEW DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity				Beam or Pipe Size (in.)
				1-4/2-6 30	2-6/3-1 40	3-1/4-15 40	4-16/6-11 30-40	
13-8	450	650	16		0	0	0	3 P
13-A-1	450	550	32			0	1	3 P
13-A-2	450	750	32			0	1	3 P
13-3	450	450	32	0	2	0	1	3 P
13-6	450	800	32		1	0	2	3 P
13-1	200	200	36	0	6	0	0	4
13-5	200	300	48		2	0	4	4
13-7	450	900	70		0	0	0	6
13-4	450	800	91		0	0	0	6
13-2	450	450	93	1	2	0	0	6
13-9	750	950	172		0	0	1	8

PLAINVIEW — 1990 CONTINUED

Signs 13-8, 13-A-1, 13-A-2, 13-3, and 13-6 were mounted on three-inch pipes. The post is mounted to the stub with 5/8 inch bolts. The specification torque for 5/8 inch bolts is 450 in-lbs. Sign 13-8, torqued to 650 in-lbs, did not have a failure. Sign 13-A-1, torqued to 550 in-lbs, suffered one failure; and sign 13-A-2, torqued to 750 in-lbs, suffered one failure. Sign 13-3, torqued to 450 in-lbs, suffered three failures. Sign 13-6, torqued to 800 in-lbs, suffered three failures.

Inconsistencies abound when trying to reconcile sign failures or nonfailures based upon the wind condition at a particular time. During the time period March 1, 1990, through April 15, 1990, no failures were observed on any of the 5 signs. However, during the time period April 16, 1990, through June 11, 1990, with the wind velocity shown as 30-40 mph, every sign suffered at least one failure, except sign 13-8 which did not have a failure. Sign 13-A-1, torqued to 750 in-lbs, sign 13-A-2, torqued to 750 in-lbs, and sign 13-3, torqued to 450 in-lbs, all suffered only one failure, while sign 13-6, torqued to 800 in-lbs, suffered two failures during the time period.

Signs 13-1 and 13-5 were mounted on S4 × 7.7 "I" beam posts. The posts were mounted to the stub with 1/2 inch bolts. The specification torque for 1/2 bolts is 200 in-lbs. Sign 13-1, torqued to 200 in-lbs, suffered six failures, all during the time period February 6, 1990, through March 1, 1990. Sign 13-5, torqued to 300 in-lbs, suffered two failures during the February 6 through March 1 period. In addition, sign 13-5 suffered four failures during the period April 16, 1990, through June 11, 1990.

Signs 13-7, 13-4 and 13-2 were mounted on W6 × 12 "I" beam posts. The posts were mounted to the stubs with 5/8 inch bolts. The specification torque for 5/8 inch bolts is 450 in-lbs. Sign 13-7, torqued to 900 in-lbs, and sign 13-4, torqued to 800 in-lbs, suffered no failures during the test period. Sign 13-2, torqued to 450 in-lbs, suffered three failures during the test period.

PLAINVIEW — 1990 CONTINUED

Sign 13-9 was mounted on W8 × 21 "I" beam posts. The posts were mounted to the stubs with 3/4 inch bolts. The specification torque for 3/4 inch bolts is 750 in-lbs. The sign bolts were torqued to 950 in-lbs and suffered one failure during the test period.

PLAINVIEW — 1991

TABLE 6A: 1991 PLAINVIEW DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity		Beam or Pipe Size (in.)
				1-17/4-2 35	4-2/5-30 40-50	
13-1	450	500	36	1	*	3 P
13-2	450	450	9	0	0	3 P
13-3	450	450	9	0	0	3 P
13-4	450	550	36	0	0	3 P
13-5	450	550	36	**	**	3 P
13-6	450	500	25	0	o	3 P

*Post blew down 5-3-91. Broke stub under base plate.

**Post blew down twice in test period. Broke base plate from post.

TABLE 6B: 1991 PLAINVIEW DATA

Sign ID	Standard Torque in/lbs	Torque in/lbs	Area S.F.	Maximum Wind Velocity		Beam or Pipe Size (in.)
				1-17/4-2 35	4-2/5-30 40-50	
13-2	450	450	9	0	0	3 P
13-3	450	450	9	0	0	3 P
13-6	450	500	25	0	0	3 P
13-1	450	500	36	1	*	3 P
13-4	450	550	36	0	0	3 P
13-5	450	550	36	**	**	3 P

*Post blew down 5-3-91. Broke stub under base plate.

**Post blew down twice in test period. Broke base plate from post.

Signs 13-1 through 13-6 were mounted on three-inch pipes. The posts were mounted to the stubs with 5/8 inch bolts. The specification torque for 5/8 inch bolts is 450 in-lbs. Signs 13-2 and 13-3 were both torqued to 450 in-lbs. Neither sign suffered a failure during the test period. Both signs had a small sign area. Sign 13-6 has a sign area of 25 square feet. Signs 13-1, 13-4, and 13-5 all have sign areas of 36 square feet. Sign 13-6, torqued to 500 in-lbs, suffered no failures during the test period. Sign 13-1, torqued at 500 in-lbs, suffered one failure from January 17 through April 4, 1991, and blew down during the remainder of the test period. Sign 13-4, torqued to 550 in-lbs, suffered no failures during the test. Sign 13-5, torqued to 550 in-lbs, blew down twice during the remainder of the test period.

CONCLUSIONS

This Test Program was set up to look into two important but possibly conflicting concerns involving the torque setting for bolts securing sign posts to sign stubs. The first concern is safety. Department sign mounting standards require a specified torque for each bolt size used in mounting signs. To violate the torque requirements could destroy the effectiveness of the breakaway sign mounting. The second concern is for sign personnel concerned with keeping the signs upright during the prevailing high winds in the spring months. Past general practice was to tighten the bolts as much as possible without regard to torque requirements. This test was intended to gather data leading to recommendations either for retaining present torque requirements, for changing present specifications or for further study. Actually, the data gathered is sometimes conflicting and contradictory. However, based upon two years of observation by section sign personnel and perceived data trends some conclusions have emerged.

During the test period, three factors affecting the signs were observed and recorded. The three factors are wind velocity, bolt torque, and sign area. Two of the factors, sign area and bolt torque, have been varied as part of the test. The sign area and bolt torque are easily determined. The wind velocity determination is a problem. Each participating maintenance section recorded a maximum wind velocity for each observation period. The wind speed was obtained either from local wind speed meters, mounted at the local section headquarters, or from the U.S. Weather Bureau or the local radio station. Thus, even if the wind speed is accurate, it is only accurate for one particular place in the county. Wind conditions can and do vary widely across the area of a county. Wind speed recordings are not considered very reliable in these tests.

Bolt torque is one of the factors used as a variable during the test. A test group of two or three signs was selected with each having approximately the same sign area. One sign was then mounted to the sign stub with bolts torqued to the

specification torque. The other sign or signs were mounted with each sign having a different torque setting. All of the signs were observed during the test period and the number of failures recorded for each. Our assumption was that each sign was subjected to the same maximum wind speed as the other signs. The test results were very inconsistent. At times the sign with the highest torque setting would have the fewest number of failures. In the next group of test signs the sign set at the highest torque might have a greater number of failures than the other signs. Our assumption is that the wind speed is a variable which we cannot measure at all test points. Without a controlled environment, i.e. controlled wind direction and velocity, we believe that it is impossible to make a comparison between results of different bolt torques. One interesting result of the test is a change in attitude among some of the section sign personnel. Some of them are now of the opinion that a large increase in the bolt torque over the specification torque can result in increased failures.

The third factor considered in the test involves the area of the sign. Rather than setting up test groups of signs with fixed torques and varying sign sizes, data were taken from the preceding tests. Some problems were very apparent. Along concurrent routes, such as IH 27 and US 87, the various routes must be shown at each intersection. This is done by placing appropriate signs on a three-inch T post. Twelve signs with a total sign area of 36 square feet are mounted with one half of the signs mounted on each arm of the T. The top of this sign is 17 feet above the slip plate. The mounting bolts are 5/8 inch and call for 450 in-lbs torque. Several of these sign locations have suffered repeated failures. In many cases, the entire sign blew down. It was not always the fault of the bolts. There have been weld failures on these signs. We do not believe the sign support is adequate for the sign load. Three-inch pipe seems to adequately support a sign area up to 16 to 20 square feet.

The construction of two sections of Interstate 27 through the city of Lubbock were completed during the summer. All ground mounted breakaway signs were mounted using the torque specified by the sign mounting standards. The signs have been standing through the fall winds but have not yet been subjected to the higher spring winds. To date there have been no bolt torque failures. During the past year, Swisher County personnel have set all replacement signs to specified torques. They report less failures than would have been expected during past years of over-torquing bolts. However, there are some signs which fail on a recurring basis for no apparent reason. Wind variation seems to be the problem. This could be an unusually high wind occurring in one location or a special wind current created by highway geometrics.

It is essential that our breakaway signs perform as they were designed to do. It is also essential that our signs remain upright when subjected to high winds. At the present time the sign mounting standards set a mandatory torque setting for each size bolt used for mounting sign posts to sign stubs. If this one torque setting for each bolt size is the only setting which will maintain the integrity of

the breakaway design, then as a general rule we must learn to "live" with that setting. As a practical measure, some of the larger signs will suffer repeated failures and require special attention. If there were some latitude for an increase in torque settings, as sign area increases, we could possibly reduce sign failure and consequent cost of sign replacement. Two of the sign types most apt to fail are all signs mounted with 1/2 inch bolts with torque settings of 200 in-lbs and the pipe mounted signs when the sign area exceeds the 16 to 20 square foot range. Signs mounted on I beam posts are also liable to failure as the sign area increases. We feel that a study of large area signs subjected to various wind directions and velocities could be revealing. However, the wind direction and velocity must be measurable at the test point to provide useable information.

RECOMMENDATIONS

1. All bolts securing sign posts to sign stubs should be set at the torque specified by sign mounting standards. All bolts should have threads burred at junction with nut.

Comment: Following this recommendation will create problems with some individual signs. These particular signs are expected to have recurring failures. However most signs are expected to perform satisfactorily, and the recurring failures should be dealt with on an individual basis.

2. Concurrent route marker signs, twelve signs with 36 square feet of sign area, which have recurring failures should be divided when possible and mounted on two posts rather than one T post.

Comment: The area where these signs are mounted is usually congested and may present problems in erecting two signs. Signs have failure problems with both the bolt joint and the weld joint. The weld joint failure is due to load stress, not improper welding.

3. Keeper plates should always be used, and shim usage should be kept to a minimum when mounting sign posts to sign stubs.

Comment: Keeper plates are essential to the proper function of the bolted joint. Shims are likely to shift and be lost from the bolted joint when subjected to sign flexing and rotation under wind loads. An increase in number of shims at the joint increases likelihood of shims shifting with consequent bolt failure.

4. Stricter inspection should be required on pipe welds for signs to be installed under construction contract.

Comment: Several pipe-mounted signs on Interstate 27 failed at the welded joint between the pipe joint and the base plate. Visual inspection indicate that the weld metal had not been properly fused with the pipe metal for the total pipe circumference.

5. A research project should investigate adequacy of presently specified torques for bolts mounting sign posts to sign stubs.

Comment: Three factors affect the ability of a sign to stay upright during its useful life. The factors are wind velocity and direction, bolt torque, and sign area. In order to secure any meaningful data concerning bolt mounting failures, the test must be in a controlled environment with the ability to measure the wind velocity and direction. Then sign area and bolt torques may be varied and results observed and compared.