Abridgment Development and Testing of a Breakaway Support

Coupling for Light Poles

Arthur M. Dinitz, Transpo-Safety, Incorporated, New Rochelle, New York Douglas B. Chisholm, Federal Highway Administration

Each year numerous injuries and fatalities occur as a result of vehicles hitting light poles adjacent to U.S. highways. Until recently the widely used transformer base has been considered "breakaway". The 1975 AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals has tightened design standards by calling for an improvement in the performance of the breakaway feature. Satisfactory dynamic performance is indicated when the maximum change in momentum for a standard 1020-kg (2250-lb) vehicle, or its equivalent-striking a breakaway support at speeds from 32 to 97 km/h (20 to 60 mph)-does not exceed 4895 nt s (1100 lb s). A "preferable" maximum change of momentum of 3337 nt's (750 lb's) is also stated in the above specifications as a goal for the future.

POLE-SAFE BREAKAWAY SUPPORT COUPLING

The Pole-Safe breakaway support coupling (longitudinally grooved) is a frangible coupling designed for use on light poles so that they will break away under impact within these criteria. The coupling (Figure 1) is made from die-cast aluminum, roughly cylindrical in shape with a 2.54-cm (1-in) 8UNC threaded hole at one end and a 2.54-cm (1-in) 8UNC 304 stainless steel stud protruding from the other end. The coupling thus provides a breakaway spacer between an existing light pole and its foundation. It fits over the anchor bolt, and the stud protrudes through the pole base plate.

Technical features of this support coupling include the following:

1. It eliminates fatigue problems in tension and bending loads that would be present with circumferentially notched couplings, shear pins, notched bolts, and so forth.

2. Longitudinal notches provide high stress concentration for rapid fracture at relatively low impact force levels.

3. Ratio of service-load capacity to failure load is higher than existing designs due to unique geometry. Ratios up to 6:1 are possible.

4. Highest possible control of fracture mode ensures repeat impact performance for any design impact load.

The Pole-Safe breakaway coupling provides both a high tensile load capacity and a low breakaway force requirement (Figure 2). Under a tensile load, the longitudinal grooves do not become stress-risers since the stress field is parallel to the groove root. Under the loading induced by an impacting vehicle as shown in the previous force and moment diagram, the loads are perpendicular to the grooves. This efficiently concentrates the stresses at the groove root. A 1020-kg (2250-lb) Vega impacting a 15-m (50-ft), 308-kg (680-lb) luminaire support at 32 km/h (20 mph) equipped with four Pole-Safe couplings experienced a peak deceleration of 8.0 g or 80 100 nt (18 000 lb). Since each coupling requires about 20 025 nt (4500 lb), i.e., $4 \times 20 025 = 80 100$ nt ($4 \times 4500 = 18 000$ lb), it appears that there is a direct relationship between the peak fracture force of each coupling and the resultant vehicle deceleration. Every effort has been made to keep impact fracture loads low while maintaining the highest possible tensile load capacity.

Developmental Program

The new nature of the technology involved in the longitudinally grooved breakaway support coupling required an extensive developmental program:

1. To determine the physical changes to the coupling that would have an effect on the desired results;

2. To expand, clarify, and prove the theory by changing all of the variables to determine their effect on the system;

3. To determine the parameters of the variables for the optimization of the system; and

4. To apply this optimization to develop a breakaway support coupling for 2.54-cm (1-in) anchor bolts as well as other sizes as needed.

It was also noted that physical changes affecting desired results included coupling size, notch depth, notch sharpness, length and other characteristics of starter notch, type and surface finish of threaded stud, and imbedment of threaded stud.

Testing Procedure and Results

Many tests have been conducted on various prototypes manufactured during the development phases for the Pole-Safe coupling. The results presented in this report are those of the production batch from which couplings were used for the vehicle crash test. The following tests were conducted:

1. Bench-type load tests-axial pull load and shear load,

2. Corrosion tests followed by axial fatigue tests, and

3. Full-scale crash tests.

Bench-Type Load Tests

Numerous axial load tests have been conducted on a Tinius Olsen tensile testing machine located at Transpo-Safety's plant. The table below gives the results of the axial load tests done on the crash test

HEAVY HEX STEEL NUT



Figure 2. Diagram shows coupling's high tensile load capacity and low breakaway force requirement.



TENSILE OR COMPRESSIVE LOAD

production lot [1 kg = 2.2 lb. Axial load-average, 27 420 lb; maximum, 30 650 lb; minimum, 26 000 lb].

Test Piece	Axial Load (lb)
CT 7-11-1	30 650
CT 7-11-2	26 000
CT 7-11-3	26 100
CT 7-12-3	26 900
CT 7-12-4	27 450

A jig for the shear load test was specially designed to fit into a Tinius Olsen tensile testing machine. The jig is two L-shaped structures positioned opposite each other with the couplings holding them together. The two structures are pulled apart laterally to simulate an impact shear load.

The shear load tests have been conducted on the same Tinius Olsen tensile testing machine as the axial load tests. The results of the shear load tests done on the crash test production lot appear in the following table [1 kg = 2.2 lb. Shear load—average, 4760 lb/ coupling; maximum, 6300 lb/coupling; minimum, 3900 lb/coupling.]:

Test Piece	Shear Load (Ib/coupling)
CT 7-11-4	6300
CT 7-11-5	3900
CT 7-11-6	5300
CT 7-12-1	3900
CT 7-12-2	4400

Corrosion Testing

Two couplings from the crash test production lot were

subjected to a salt spray test for 336 hours at the Pittsburgh Testing Laboratory, Pittsburgh, Pennsylvania, in accordance with ASTM B117, which is basically exposure to 5 percent salt fog at 35°C (95°F).

The results showed a very slight pitting on the threaded stainless steel stud. However, no evidence of pitting or corrosion was noted anywhere on the aluminum coupling including the inside threaded area.

Fatigue Testing

The fatigue testing consisted of applying an oscillating force in tension along the axis of the threaded stud provided in the Pole-Safe coupling. The tensile load fluctuated between 227 kg (500 lb) and 4536 kg (10 000 lb) at a rate of 1800 cycles/min. Again, these test criteria are directly comparable to the Alco tests.

The first two tests were done on production lots manufactured in late May 1977. The results were no failures in 1 000 000 cycles applied in both sample 1 and sample 2.

The second two tests were done on one of the samples from the corrosion tests and one from the crash test production lot. The results were sample 1 from crash test production lot, 1.003×10^6 cycles applied, no failure; and sample 2 from crash test production lot, 1.003×10^6 cycles applied, no failure.

Vehicle Crash Testing

A full-scale vehicle crash test was conducted at the Texas Transportation Institute, College Station, Texas, on July 20, 1977, in basic conformance with NCHRP Report 153 and AASHTO specifications (Figures 3, 4, 5, 6). The test data and results were as follows:

1. Couplings: 4 production lot Pole-Safe couplings -2.54 cm (1-in) in diameter;

2. Pole: a steel 15-m (50-ft) mounting height pole with a 228-cm (7.5-ft) mast arm and a 34-kg (75-lb) weight simulating luminaire, total weight = 306 kg (676.8 lb);

3. Footing: reinforced concrete 76.2 cm dia. \times 198 cm deep (30 in dia. \times 78 in deep) with 34.2-cm (13.5-in) bolt circle with four 2.54-cm (1-in) anchor bolts extending 6.98 cm (2.75 in) above concrete footing;

4. Vehicle: Chevrolet Vega weighing 1020 kg (2290 lb);

5. Accelerometer data: approximate impact velocity, 33.1 km/h (20.6 mph);

Figure 3. Footing and base of Pole-Safe coupling in place for production lot test.



Figure 4. Pole-Safe coupling breaks away on vehicle impact.



- 6. Peak deceleration: 8 g;
- 7. Average deceleration: $\bar{0}.74$ g; and
- 8. Change in momentum: 2403 nt s (540 lb s).

Pendulum Impact Testing

Three pendulum impact tests were conducted by Ensco, Incorpated, Springfield, Virginia, utilizing Pole-Safe 101 2.54-cm dia. (1-in dia.) couplings from the crash test production lot. In all of these tests, the 1020-kg (2250-lb) soft-nosed pendulum impacted the support at a height of 45.7 cm (18 in) and at a speed of approximately 32 km/h (20 mph).

Test 1 (604) utilized the couplings under a Hapco spun aluminum 15-m (50-ft) mounting height pole. Change of momentum produced was 2363 nt \cdot s (531 lb \cdot s).

Test 2 (605) had the Pole-Safe couplings mounted under a New York City aluminum transformer base. The momentum change was 3685 nt's (828 lb's).

Test 3 (606) has the Pole-Safe couplings mounted under a Pfaff and Kendall TB-2A cast aluminum transformer base. The change of momentum resulting was 2968 nt^s (667 lb^s). No damage to the pole or the anchor bolts occurred in any of these tests. Figure 5. Coupling after breakaway.



Figure 6. Closeup of coupling after breakaway.



CONCLUSIONS

1. The Pole-Safe couplings meet the latest AASHTO and federal criteria for use as a breakaway light pole support system.

2. Since light poles and mast arms were not damaged in vehicle and pendulum crash tests, it is reasonable to believe that most poles installed with these couplings will be reusable after impact.

3. Since the anchor bolts in the vehicle and pendulum crash tests were not bent or damaged with the Pole-Safe couplings, it can be expected that highway use experience will be similar.

ACKNOWLEDGMENT

We wish to thank Gordon Samuelson of the Texas Transportation Institute and Jeffrey Bloom of Ensco, Incorporated, for their contributions to this report.

Notice: The Transportation Research Board does not endorse products or manufacturers. Trade and manufacturer's names appear in this report because they are considered essential to its object.