Dynamic Tests of Breakaway Lighting Standards by Using Small Automobiles

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The triangular steel multidirectional slip base for use on lighting standards was first developed and successfully tested in 1967 by the Texas Transportation Institute (TTI) (1). In 1968, the California Division of Highways performed a series of full-scale dynamic impact tests to evaluate the effectiveness of various types of breakaway devices used on 8.7-m-high (28.5-ft-high) lighting standards with 3.6-m-long (12-ft-long) mast arms, and, in two of the tests, a modified version of the original multidirectional slip base was used. Under the conditions of the 1968 California test, the modified multidirectional slip base proved to be an extremely effective breakaway device when impacted at both high and low speeds by a large automobile and was considered superior to the other designs tested in that series (2).

Since the developmental slip base tests performed by TTI and the California Division of Highways, changes have occurred in slip base and lighting standard design, and the size and weight of the average passenger vehicle have decreased. Lighting standard design changes include larger diameter, thicker walled standards with longer mast arms. Changes in slip base design include use of a keeper plate to prevent base "walking" during heavy wind loads, smaller diameter high-strength slip base clamping bolts, higher clamping bolt tensions, and use of hot-dip galvanized slip base parts. The effects of these changes on the performance of the slip base, especially when impacted by a small automobile, were unknown.

RESEARCH SUMMARY

The objective of this project was to determine the effectiveness of the slip base currently used by the California Department of Transportation on long-masted (type 31) steel lighting standards when subjected to full-scale impact tests by small automobiles. Impact test procedures as specified by the National Cooperative Highway Research Program (3) were followed throughout this project.

Before full-scale impact tests were performed, a study was performed to determine the torque-tension relationship for 22.2-mm-diameter (7/8-in-diameter) galvanized A325 slip base clamping bolts. A curve showing this relationship was developed and used to establish the average applied torque values required to attain the specified design bolt tensions (clamping forces). After the preliminary bolt torque-tension investigation, two impact tests (tests 311 and 312) were conducted. In each test a Ford Pinto weighing 1027 kg (2265 lb) and a slip base assembly on a 10.7-m-high (35-ft-high), 450-kg (992-lb) California Department of Transportation type 31 steel lighting standard were used. The length of the mast arm was 9.1 m (30 ft). The impact speed of the vehicle and the tension in the slip base clamping bolts were important factors in both tests. A higher clamping force is required where longer mast arms are employed to prevent separation of the slip base plates that can occur because of wind loads.

The operation of the slip base and trajectory of the lighting standard were observed at both low, 7.8-m/s (17.5-mph), and medium, 15.4-m/s (34.5-mph), vehicle impact speeds. Strain gauges in each of the three slip base clamping bolts enabled individual bolt tensions, 88.1 kN (19 800 lb) and 67.2 kN (15 100 lb) for crash tests 311 and 312 respectively, to be measured just before each impact test. In both tests, the vehicle and dummy driver were instrumented with accelerometers at critical points so that motion and deceleration data could be recorded and used to determine impact severity. Time intervals between recorded electrical impulses from tape switches mounted on the ground at known distances were used to calculate vehicle speed at various instants during the impact tests.

Table 1 gives a summary of the results of impact tests 311 and 312. The Transportation Laboratory of the California Department of Transportation has written a detailed report (4) of the research performed.

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Figure 1. Slip base used with type 31 lighting standard in crash tests 311 and 312.

1. 22.2-mm diameter ASTM A325 galvanized clamping bolts (total 3 per slip base) instrumented with strain gages.
2. 22.2-mm diameter HS anchor bolts (total 3 per slip base) cut flush with top of ASTM A564 Grade 2H galvanized nuts to allow top base plate to slip.
3. 12.7-mm thick steel plate washers (2 per clamping bolt, total 6 per slip base).
4. Surface of foundation beneath slip base clamping bolt heads relieved to provide minimum 3.2-mm clearance.
5. Hardened flat washers (1 per clamping bolt - 1 per anchor bolt, total 6 per slip base).
6. .102-mm galvanized steel keeper plate (one per slip base).

Note: 1mm = .0394 in.

Table 1. Summary of results from impact tests 311 and 312.

Item	Test 311	Test 312
Desired velocity of vehicle, m/s	9.2	17.9
Initial velocity of vehicle, m/s (average over a 1.22-m interval before impact)	7.8	15.4
Final velocity of vehicle, m/s (average over a 0.61-m interval after impact)	4.8	12.2
Change in momentum of vehicle during impact, kN·s	3.065	3.318
Time duration of vehicle contact with pole, s	0.181	0.069
Time required for slip base separation, s	0.055	0.028
Front end deformation of vehicle, mm (measured at bumper height)	432	470
Longitudinal deceleration at the center of gravity of vehicle, m/s^2 (50-ms average)	48.5	47.6
Vehicle kinetic energy at impact, kJ	31.3	122.1

Note: 1 m/s = 2.237 mph. 1 m = 3.281 ft. 1 kN·s = 0.000 225 lbf. 1 mm = 0.0394 in. 1 m/s^2 = 0.102 g. 1 kJ = 0.000 738 ft·lbf.

CONCLUSIONS

The following four conclusions are based on results from full-scale tests 311 and 312 of a Ford Pinto automobile impacting a type 31 lighting standard.

1. The triangular steel slip base currently used by the California Department of Transportation on its types 30 and 31 lighting standards is an effective breakaway device when impacted by small automobiles. Even with the heavier pole, the base slips with a relatively low loss in vehicle momentum at both low and moderate vehicle impact velocities, thus offering minimal breakaway resistance at impact.

2. Higher tensions [up to 88.1 kN (19 800 lb)] in the slip base clamping bolts that were almost twice those previously specified by California DOT did not adversely affect the slip characteristics of the base tested.

3. When a small vehicle having a roof impacts a current type 31 lighting standard with a slip base, neither the initial car-pole impact nor the trajectory and final position of the lighting standard are expected to create serious hazards or injuries to either occupants of the impacting vehicle or passengers of vehicles in adjacent traffic lanes.

4. Damages to the small vehicle in both impact tests were limited to the front end and were less than anticipated. Total costs of completely repairing the Pinto following impact test 311 were approximately $730.

RECOMMENDATIONS

The use of the current California DOT slip base design on types 30 and 31 lighting standards as shown on drawings ES-30A and ES-30B of Standard Plans (5, pp. 241 and 242) should be continued with minor modifications as shown below and in Figure 1:

1. Torques on each of the three slip base clamping bolts should be increased to 203 N·m (150 ft·lb) to ensure a long service life by reducing bolt fatigue;

2. The thickness of the rectangular plate washers used at the top and bottom of each slip base clamping bolt should be increased from 7.9 mm (5/16 in) to 12.7 mm (1/2 in) and minimum steel requirements should conform to the requirements of ASTM A 108;

3. A maximum manufacturing tolerance of ±3.2 mm (±1/8 in) should be specified for the 356-mm (14-in) slip base clamping bolt circle diameter of both the upper and lower slip base plates to avoid adverse bending and yielding of plate washers.

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