Abridgment

Crash Test Performance of a Guardrail Median Barrier and Temporary Construction-Zone Crash Cushion

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The viability of crash cushions for protecting errant motorists who hit roadside hazards is well established. An acceptable treatment for the narrow hazards created by recent widespread deployment of metal-beam guardrails and concrete median barriers (CMB) was not available prior to 1976. Southwest Research Institute of San Antonio, Texas, reported that "even at shallow angles of impact, vehicle stability is marginal..." with the long-ramp treatment of CMBs in New Jersey as recommended in Michie and Bronstad (3). The sloping transition sections—with ends buried beneath grade—eliminated impacting against blunt ends of CMBs or impalement by metal-beam guardrails but often caused ramping and subsequent rollover of errant vehicles. Existing crash cushion systems were too wide for narrow hazards; reducing their width left unit stability and side-angle redirection performance open to conjecture. In addition, rapidly expanding numbers of accidents in construction zones, created in part by temporary guardrail or CMB installations to detour traffic, dictated a need for temporary protection of work crews and motorists.

The GuardRail Energy Absorbing Terminal (G-R-E-A-T) and G-R-E-A-T Construction Zone (G-R-E-A-T_{cz}) are restorable attenuator systems developed to cushion both the narrow stationary and construction zone hazards. Both systems conform to the test standards for crash cusions outlined in Bronstat and Michie (4). Because the G-R-E-A-T is often used in bidirectional traffic, an additional test, for a wrong-way side-angle impact, was determined necessary to establish its performance suitability. This report describes the units, the test series, and the test results.

UNIT DESCRIPTION

The G-R-E-A-T crash cushion consists of crushable Hi-Dri Cartridges surrounded by steel thrie-beam guardrail. When hit head-on, thrie-beam fender panels telescope backward, permitting the impact energy to be dissipated in crushing the lightweight-concrete Hi-Dri cells. When impacted on the side, the side panels redirect the errant vehicle away at a shallow exit angle.

The nose section consists of a Hi-Dri Cartridge and a soft plastic nose wrap. This molds itself to the shape of the impacting vehicle. A G-R-E-A-T unit contains as many bays as is determined necessary to satisfy the allowable *g* loads on the impact vehicle. Each bay has a diaphragm, a Hi-Dri Cartridge, and two fender panels.

The Hi-Dri Cartridge contains many cylindrical lightweight concrete cells whose performance is documented by Walker and others (1). These cells are bonded to plywood retainer panels and encased in a moisture-resistant box. A thin plastic cover shrouds the cartridge and provides additional resistance to moisture penetration. The diaphragm consists of a short length of thrie-beam supported by two steel pipe legs.

Short sections of overlapping 10-gauge steel thrie-beam guardrail are fastened together through slotted holes that allow the panels to slide alongside one another in a telescoping manner when hit head-on. When hit on the side, the overlapping thrie-beam side panels form a truss that distributes the force of the impact along its entire length.

One end of the anchor chains is attached to a restraining chain rail that, in turn, is fastened to a concrete base. The other end of the chain attaches to a pin on the front side of the diaphragm support legs. The chains restrain the diaphragms when hit on the side but slip off the open-end leg pins when hit head on to allow the system to telescope.

When the G-R-E-A-T is used in a median barrier application where traffic is going the wrong way on the left side of the unit, deflector panels are attached to the back end of each fender panel and to the backup (see Figure 1) so that wrong-way traffic cannot snag on the backup or exposed ends of the fender panels.

This same crash cushion placed on a metal platform can quickly be bolted to a concrete surface; because of its transportability, it is ideally suited for providing the same effective protection at construction sites.

G-R-E-A-T_{cz}

Except for the addition of the portable steel platform (see Figure 2), the system is identical to a permanent G-R-E-A-T installation. Expansion-type anchor bolts secure the platform to a concrete base. For transportation the unit is separated at the splice in the base plates and lifted by using the tabs on the base plates. Each plate weighs approximately 635 kg (1400 lb), including the G-R-E-A-T unit.

No effective means has yet been found for attaching the G-R-E-A-T_{cz} platform to soil or to asphalt bases. Therefore, a concrete base of suitable size to prohibit movement during impact is necessary.

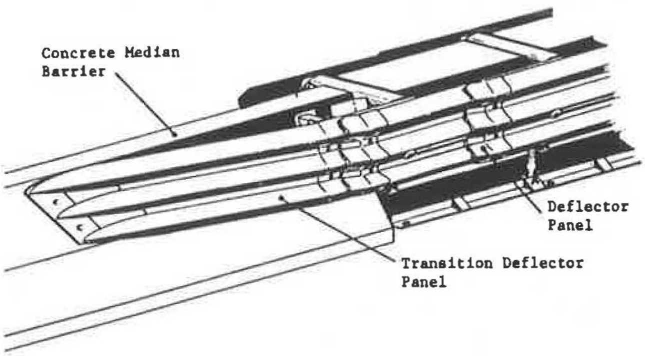
Restoration of the G-R-E-A-T and G-R-E-A-T_{cz} can be quickly achieved by pulling the unit out to its preimpact position and replacing the expended cartridges and shear pins. Refurbishment, in most cases, can be completed in approximately 30 min. Figure 3 shows the G-R-E-A-T system installed on the end of a guardrail.

TEST DESCRIPTION

The four tests conducted for Federal Highway Administration (FHWA) approval and the wrong-way side-angle impacts are reported herein. Test criteria conformed with requirements outlined in Bronstad and Michie (4).

The test unit was 0.76 m (30 in) wide and contained six bays and a nose section—total length equalled 6.4 m (21 ft). Data were acquired with longitudinal and transverse accelerometers mounted on the vehicle floorboard immediately behind the driver's seat. Acceleration data were fed through a hard line to a Dixson paper tape recorder located in a stationary vehicle. Two high-speed cameras, a Fastax filming at 1000 frames/s and a Photosonic filming at 500 frames/s, provided backup instrumentation. Standard targets were painted on the vehicles, and a high-speed timer was included in the photometric record.

Figure 1. G-R-E-A-T system median barrier protection.



Test 1—Heavy Car, Centered on Unit Nose

The test vehicle was a 1960 Pontiac two-door sedan, weighing 1845 kg (4060 lb). Impact velocity was 101 km/h (63 mph), with impact occurring on the nose at a 0° angle to centerline and 0.46 m (18 in) to the right of the unit centerline.

During the impact, the test vehicle rotated counterclockwise 48°, rotating as the forward motion of the vehicle was virtually completed. The vehicle was permanently deformed approximately 0.36 m (14 in) on the front left side.

The accelerometer trace indicated the vehicle was subjected to an average deceleration of 8.0 g, with forces exceeding the 12-g level twice, once at 50 ms and again at 75 ms after initial impact, for 15 ms duration each. The peak load was 15 g. Except for the cartridges, the unit sustained no damage.

Test 2—Light Car, Centered on Unit Nose

In this test a 1971 Vega station wagon, weighing 1077 kg (2370 lb), impacted at 93.4 km/h (58 mph) on the center of the unit at a 0° angle to centerline. The vehicle rotated approximately 40°, but not until the forward motion neared completion. Vehicle deformation was approximately 0.25 m (10 in). Immediately after impact, the impact vehicle was started and driven for a short distance.

Average deceleration force was 7.8 g, exceeding 12 g for 20 ms duration beginning 50 ms after impact. Peak load was 13 g. Again, except for the cartridges, no unit damage was observed.

Figure 2. G-R-E-A-T system (portable) for construction zones.

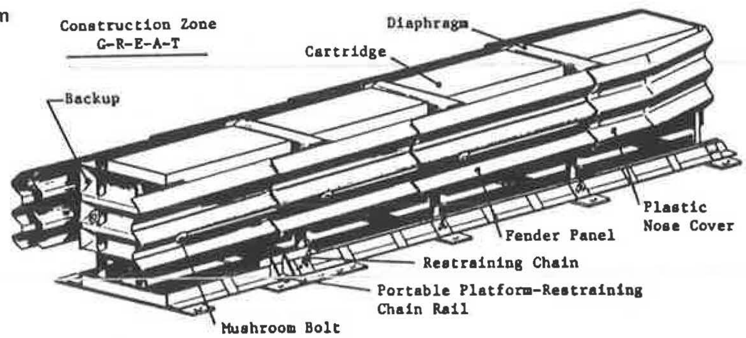


Figure 3. G-R-E-A-T system installed at end of guardrail.

Test 3—Heavy Car, 20° Side-Angle Impact at Midlength

The test vehicle was a 1968 four-door Buick LeSabre sedan, weighing 2054 kg (4520 lb), impacting at 101.4 km/h (63 mph) at midlength, at an angle of 20° as measured from unit centerline. The vehicle was gently redirected, exiting at an angle of 7°, and traveled approximately 274 m (900 ft) before drifting slightly to the left and stopping. The vehicle sustained significant sheet-metal damage on both front and rear fenders with only slight damage to the doors. The same vehicle was driven live the following day in a test series on a different unit.

Maximum transverse and longitudinal deceleration forces were 3 and 6 *g* respectively. No unit damage was discernible, nor were any cartridges expended. In normal service no maintenance would have been required.

Test 4—Heavy Car, 0-0.9m (0-3 ft) Offset From Unit Nose, 10-15° Impact Angle

The test vehicle was a 1968 Oldsmobile four-door hardtop, weighing 2050 kg (4510 lb). The impact point was on the center of the nose, but at a 10° angle with the unit's centerline. Impact velocity was 93.4 km/h (58 mph). The vehicle momentarily tended to rotate and follow the unit as it compressed, but then continued its approximate preimpact path until coming to a stop. Before stopping, the vehicle rotated to the left until it was oriented at a 30° angle to the unit centerline.

Compression of the G-R-E-A-T was normal until the final instant when the vehicle rotated left. One of the longitudinal slots on a right fender panel deformed, allowing a mushroom washer to pull out. Subsequently, the unit separated at that point and rotated clockwise through an arc of approximately 90°.

Damage to the vehicle was confined to a permanent centerline front-end deformation of approximately 0.36 m (14 in). Attenuator damage was limited to deformation of four fender panels, requiring either straightening or replacement, and expenditure of all frangible cartridges. Complete refurbishment was accomplished in approximately 1 h.

Average deceleration force for the event was 7.7 *g*. The force exceeded 12 *g* for a period of 15 ms, and the peak force was 13 *g*.

Tests 5 and 6—Wrong-Way Side-Angle Impacts

In the first wrong-way test, a 1967 1682-kg (3700-lb) Chevrolet was directed into the wrong-way thrie-beam transition panel, between the backup and concrete median barrier, at an angle of 20° and at 74 km/h (46 mph). Redirection was smooth, and the vehicle suffered only minor sheet-metal damage.

In the second wrong-way test, a 1966 Buick, weighing 1873 kg (4120 lb), impacted the side of the unit at approximately midlength of the unit at an 18° angle and at 88.5 to 96.6 km/h (55 to 60 mph). The vehicle was smoothly redirected at approximately a 6° exit angle with a minor change in velocity.

SUMMARY AND CONCLUSION

Live drivers involved in tests at speeds of up to about 80 km/h (50 mph) have reported no discomfort from restraining belts in both head-on and side-angle impacts. Southwest Research Institute has conducted one additional test on the G-R-E-A-T system, the results of which are described in Bronstad, Calcote, and Kimball (2).

The remainder of the functional tests conducted on the G-R-E-A-T system to date have displayed characteristics similar to those discussed above in performance, damage sustained, replacement parts required, and refurbishment considerations.

Test results proved that the G-R-E-A-T system satisfied the requirements established for serviceable impact attenuators. Actual in-service data obtained from the hundreds of units in use in the field nationwide have corroborated the results of the evaluation test series. These data prove that the G-R-E-A-T either safely stops or redirects errant vehicles, which might otherwise impact against narrow hazards.

The portable G-R-E-A-T system has had limited exposure due to its recent implementation in field service. However, initial feedback from several highway department construction projects has been favorable regarding ready transportability and installation. It is expected that additional data will continue to indicate utility and performance on a par with that of the permanent G-R-E-A-T system.

REFERENCES

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3. J. D. Michie and M. E. Bronstad. Location, Selection, and Maintenance of Highway Traffic Barriers. NCHRP, Rept. 118, 1971, pp. 48-55.
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