ET Plus® Development History

The Evolution of Roadside Safety Devices

Guardrails perform a fundamental safety role on highways. A long-standing engineering challenge has involved vehicles striking the end of a guardrail head-on. Efforts to reduce the impact of such high-speed, head-on crashes have included the Breakaway Cable Terminal and turned-down guardrail end, among others. But each effort had its drawbacks. For example, the turned-down guardrail end successfully eliminated the spearing hazard associated with blunt-edged rail, but caused some small vehicles to vault or rollover.

In the 1980s, Texas A&M Transportation Institute (TTI) research engineers who analyzed the problem developed what came to be known as the ET-2000, the forerunner of the ET Plus® System that is in widespread use today. The ET-2000 was the first energy-absorbing guardrail end treatment and was revolutionary in its design. By absorbing vehicle energy, the ET-2000 enhanced the chances that the driver and passengers would survive in a high-speed, end-on crash.

The impact head on the ET-2000, which was designed to meet federal crash testing criteria, includes an extruder throat, an impact plate, and "guide channels." In end-on impacts, the flattening and bending of the guardrail section away from the vehicle (a process called "rail extrusion") helps to slow the vehicle after impact. The guide channels help keep the impact head aligned with the guardrail during an end-on impact to enable the rail extrusion process to take place, if impacted within federal guidelines.

The ET-2000 was further designed to accommodate end-on impacts at an angle through a process known as "gating." Gating occurs when the impacting vehicle pushes the impact head out of alignment with the guardrail. The guardrail bends and forms a hinge about which the impact head rotates and swings away from the vehicle.

The amount of vehicle energy that is dissipated during an end-on impact depends on a number of factors, including impact angle. If a vehicle impacts the terminal end-on at zero degrees with the center of the vehicle aligned with the terminal system, a substantial amount of energy will be dissipated, and the vehicle may even come to a complete stop. However, it is more common for a vehicle to impact the terminal end-on at an angle to the system. In such circumstances, the vehicle will "gate" through the terminal system and some energy may be dissipated through rail extrusion in the process.

Testing the ET-2000 Guardrail End Treatment

The ET-2000 was successfully subjected to vehicle crash testing following the guidelines of National Cooperative Highway Research Program (NCHRP) *Report 230*, and was accepted by the Federal Highway Administration (FHWA) in 1989. The design proved successful in its first documented field impact when a motorist impacted an ET-2000 on Interstate 35 near Buda, Texas, in March 1991 and walked away without injury. Similar results throughout the country occurred and the developers of the ET-2000 were recognized for their efforts with the 1991 Federal Highway Administrator's Biennial Safety Award.

As with all guardrail end-terminal systems, the ET-2000 was tested to specific design impact conditions and evaluation criteria as outlined in national-testing guidelines. The design impact conditions are prescribed in terms of vehicle type, weight, impact speed, impact angle, and impact location.

In 1993, *NCHRP Report 350* was published, outlining a comprehensive update of crash test and evaluation procedures. It reflected the changing character of the highway network, such as higher speeds, and the vehicles using it, including the adoption of a pickup truck as a new design test vehicle.

The FHWA formally adopted the new performance-evaluation guidelines for highway safety features set forth in *NCHRP Report 350* and mandated that, starting in September 1998, only highway safety devices that meet *NCHRP Report 350* test criteria could be used on new construction projects on the National Highway System (NHS).

Pursuant to this requirement, the ET-2000 was successfully tested in accordance with *NCHRP Report 350* in 1995, and received FHWA acceptance that same year (ref. FHWA letter CC-12C dated 8/22/1995).

Development of the ET Plus® End-Terminal System

TTI researchers continued to explore opportunities to improve the extruder-terminal technology, as they do with many other highway technologies. Seeking to improve the technology for end-terminal systems, TTI research engineers developed the ET Plus® end-terminal system. The ET Plus® retained the same extrusion throat mechanism of the ET-2000, but incorporated several significant design improvements to enhance safety. Some of the design improvements included:

- Extending the impact plate to accommodate a broader range of vehicles (from small passenger cars to taller pickup trucks); and
- Reducing the weight of the impact head to lessen the crash impulse on an impacting vehicle and, thereby, reducing crash severity and probability of occupant injury.

TTI conducted *NCHRP Report 350 Test 3-31,* an end-on impact with a 4400-lb pickup truck at zero degrees and 62 mph, on the ET Plus®. The selection of this test was made in consultation with FHWA. Based on the success of this test and previous testing of the ET-2000, which had the same extrusion throat as the ET Plus®, the new ET Plus® end-terminal system was accepted by FHWA for use on the National Highway System (NHS) in letter CC-12G dated 1/18/2000.

Based on FHWA's collective evaluation of a full battery of tests run on the ET-2000, and the results of the 3-31 testing, the FHWA did not require further crash tests to conduct its evaluation.

Although end-on impact performance of the ET Plus® met test criteria, TTI research engineers observed that the ET Plus® impact head with five-inch guide channels had more room than necessary within the guide channels. TTI research engineers realized that they could enhance impact performance of the ET Plus® by improving alignment of the head on the rail. This was accomplished by narrowing the guide channels from 5 inches to 4 inches.

TTI researchers recommended the change in the guide channels to Trinity, which is the exclusive licensee and manufacturer of the ET Plus® System. After a manufacturing-review process, Trinity concluded that an ET Plus® impact head with four-inch guide channels could be manufactured.

Improvements to the ET Plus® End-Terminal System

In 2005, Trinity proposed to TTI research engineers to incorporate an ET Plus® impact head with four-inch guide channels into an ongoing crash-testing program being performed to evaluate the ET Plus® system installed on 31-inch high guardrail. Upon TTI review and approval of a Trinity-fabricated prototype, an ET Plus® impact head with 4-inch guide channels was included in a successful small car end-on crash test (*NCHRP Report 350 Test 3-30*).

Based on the successful performance in accordance with *NCHRP Report 350* test criteria, the ET Plus® end-terminal system at the 31-inch guardrail height, including an ET-Plus impact head with four-inch guide channels, was accepted by FHWA for use on the NHS in letter CC-94 dated 9/02/2005.

In 2010, TTI conducted two end-on crash tests of the ET Plus® terminal system, which successfully met *NCHRP Report 350* test criteria. Both crash tests were performed on systems that included an ET Plus® head with four-inch guide channels. In the first of the two tests, a *NCHRP Report 350 Test 3-30* was performed to evaluate use of standard steel-line posts in the end-terminal system at an increased impact speed. The test successfully met all *NCHRP Report 350* evaluation criteria.

In the second test in 2010, *NCHRP Report 350 Test 2-30* was conducted to evaluate the ET Plus® system at lower impact speeds (i.e., 44 mph rather than 62 mph). Once again, the ET Plus® terminal system with 4-inch guide channels satisfied all *NCHRP Report 350* test criteria. The test results for the two tests did not require formal submission to FHWA in 2010 because the FHWA accepted the proposed installation configurations based on other testing considerations.

The reports and test results for both of these tests were subsequently given to FHWA in February 2012. FHWA reviewed the reports and testing results of the ET Plus® with 4-inch guide channels and the FHWA confirmed its continuous eligibility for use on the NHS on several occasions. More specifically, FHWA sent confirming notifications to state DOTs in October 2012, the Association of State Highway and Transportation Officials (AASHTO) in January 2013, and FHWA Division Offices in June 2014.