December 23, 2009

In Reply Refer To:
HSSD/CC-106

Mr. Andy Keel, P.E.
Roadway Design Standards Engineer
605 Suwannee Street, MS 32
Tallahassee, FL 32399-0450

Dear Mr. Keel:

This letter is in response to your request for the Federal Highway Administration (FHWA) acceptance of a roadside safety device for use on the National Highway System (NHS).

Name of device: Florida Low-Profile Barrier Terminal
Type of device: End Terminal
Test Level: TL-2
Testing conducted by: E-Tech Testing Services, Inc., Rocklin, CA
Date of request: October 19, 2009
Date initially acknowledged: October 19, 2009
Date of completed package: November 27, 2009
Task Force 13 Designator: SER-04

You requested that we find this device acceptable for use on the NHS under the provisions of National Cooperative Highway Research Program (NCHRP) Report 350 “Recommended Procedures for the Safety Performance Evaluation of Highway Features.”

**Requirements**

Roadside safety devices should meet the guidelines contained in the NCHRP Report 350 or the American Association of State Highway and Transportation Officials’ Manual for Assessing Safety Hardware (MASH). The FHWA Memorandum “Identifying Acceptable Highway Safety Features” of July 25, 1997, provides further guidance on crash testing requirements of longitudinal barriers.
Description
The Florida Low-Profile work zone concrete (low-profile) barrier was earlier approved for use on the NHS as per FHWA Acceptance Letter HSA-10/B-115 dated August 12, 2003. The height of this low profile barrier is 18 inches. A study was conducted of existing end terminals successfully tested as per NCHRP 350 to specify with this low-profile barrier. This study revealed all end terminals were taller than 18 inches. Furthermore, none of the end terminals researched were compatible with the unique barrier-to-barrier connection system used by this low-profile barrier system. Upon impact this connection will simultaneously engage adjoining barrier segments. Barrier resistance in both inertial mass and contact surface friction serves to redirect the Test Level 2 (TL-2) impact force without requiring any positive mechanical anchorage to the roadway surface (e.g. vertical steel pins). This low-profile barrier also serves in providing an unobstructed driver view of cross-traffic.

The following design goals were established to develop a new end terminal for the Florida low-profile barrier.

- End terminal shall have a maximum height equal to or less than the height of the low-profile barrier segments (18 in.).
- End terminal shall not require mechanical anchorage to roadway surface, but instead shall rely on a combination of inertial mass resistance and flexural continuity with the low-profile barrier.
- End terminal shall be capable of being connected to the key and/or keyway ends of the low-profile barrier segments using a compatible connection system.
- For ease of transportation, handling, and installation, the end terminal shall be composed of segments that are relatively short in length (no longer than the 12 ft. length of the low-profile barrier segments).
- End terminal components shall be fabricated from materials that are durable with respect to impact loading, transportation, handling, and installation.

In addition, it was also determined that a barrier height of less than 18 in. would not provide the necessary level of safety with regard to vehicle redirection and resistance to vehicle rollover. Therefore there exists a diminished likelihood the tapered end terminal will successfully redirect a full-size pickup truck. For this reason, no part of the end terminal is considered to contribute to the required length of need (LON) of barrier to protect a particular work zone.

The end terminal is 20 ft. long. It is composed of two sections, (1) 12-ft. long reinforced concrete segment and (1) 8-ft. steel segment. The end terminal height varies from 18 inches at the point of connection to the low-profile barrier, tapering to 2 inches at the end of the end terminal. An innovative connection system and a nearly symmetric shape make the end terminal reversible. This reversibility permits the end-treatment to be attached to either the key or keyway ends of low-profile barrier segments. Neither the end terminal nor the low-profile barrier to which it attaches requires any mechanical anchorage to the roadway surface. This design was completed using a combination of numerical finite element impact simulation followed by full-scale crash tests per the requirements of NCHRP Report 350. The finite element impact analysis was used to establish the geometric shape of the end terminal and to quantify design forces.
Crash Testing

Full-scale crash tests conducted on the Florida low-profile barrier (Consolazio et al. 2003) were carried out in accordance with the longitudinal barrier requirements of NCHRP Report 350. Testing was conducted at TL-2 conditions (45 mph impact speed), hence the design and testing of the end terminal shall also correspond to 45 mph impact conditions. The newly developed end terminal shall be designed and tested as a gating terminal device. The following crash tests are required as per NCHRP Report 350 for a gating end terminal (descriptions have been adapted from Beason et al. 1998):

- **NCHRP 350 test designation 2-30.** This test involves an 820 kg passenger vehicle approaching parallel to the road way and impacting the end-treatment at a nominal speed and angle of 43.5 mph (70 km/h) and 0-degrees with the quarter point of vehicle aligned with the centerline of the end terminal. This test is intended to evaluate occupant risk and vehicle trajectory.

- **NCHRP 350 test designation 2-31.** This test involves a 2000-kg pickup truck impacting the end-treatment at a nominal speed and angle of 43.5 mph (70 km/h) and 0-degrees with the center line of vehicle aligned with the centerline of the end terminal. The purpose of this test is to evaluate the capacity of the end terminal to absorb the kinetic energy of the 2000-kg vehicle (in terms of structural adequacy criteria) in a safe manner (occupant risk).

- **NCHRP 350 test designation 2-32.** This test involves an 820-kg passenger vehicle impacting the end terminal at a nominal speed and angle of 43.5 mph (70 km/h) and 15-degrees with the center line of the vehicle aligned with the centerline of the nose of the end terminal. This test is intended to evaluate occupant risk and vehicle trajectory.

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- **NCHRP 350 test designation 2-35.** This test involves a 2000-kg pickup truck impacting the end terminal at a nominal speed and angle of 43.5 mph (70 km/h) and 20-degrees with the front corner of the vehicle impacting at the beginning of the length of need (LON). This test is intended to evaluate the ability of the end terminal to contain and redirect the pickup truck within vehicle trajectory criteria.
• **NCHRP 350 test designation 2-39.** This test involves a 2000-kg pickup truck impacting the end terminal from the reverse direction at a nominal speed and angle of 43.5 mph (70 km/h) and 20-degrees at the mid-length of the end terminal. This test is intended to evaluate the performance of the end terminal for a reverse impact.

**Findings**

Using simulation and physical crash testing, a new crashworthy end terminal was developed for specification with the Florida low-profile barrier system. Based on results obtained from separate simulations, the minimum required lateral deflection space that provides adequate barrier performance in drop-off zone applications is 6 in. for an impact speed of 45 mph. Subsequently, the end terminal was structurally-designed, fabricated, and subjected to a series of seven full-scale crash tests per the TL-2 requirements of NCHRP Report 350. Crash tests involving both a small car (820kg) and a full-size pickup truck (2000 kg) were successfully passed. The test data summary sheets are enclosed for reference.

Therefore, the device described in the request above and detailed in the enclosed drawings is acceptable for use on the NHS under the range of conditions tested, when acceptable to a highway agency.

**Standard provisions**

Please note the following standard provisions that apply to FHWA letters of acceptance:

• This acceptance is limited to the crashworthiness characteristics of the devices and does not cover their structural features, nor conformity with the Manual on Uniform Traffic Control Devices.
• Any changes that may adversely influence the crashworthiness of the device will require a new acceptance letter.
• Should the FHWA discover that the qualification testing was flawed, that in-service performance reveals unacceptable safety problems, or that the device being marketed is significantly different from the version that was crash tested, we reserve the right to modify or revoke our acceptance.
• You will be expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.
• You will be expected to certify to potential users that the hardware furnished has essentially the same chemistry, mechanical properties, and geometry as that submitted for acceptance, and that it will meet the crashworthiness requirements of the FHWA and the NCHRP Report 350.
• To prevent misunderstanding by others, this letter of acceptance is designated as number CC-106 and shall not be reproduced except in full. This letter and the test documentation upon which it is based are public information. All such letters and documentation may be reviewed at our office upon request.
This acceptance letter shall not be construed as authorization or consent by the FHWA to use, manufacture, or sell any patented device for which the applicant is not the patent holder. The acceptance letter is limited to the crashworthiness characteristics of the candidate device, and the FHWA is neither prepared nor required to become involved in issues concerning patent law. Patent issues, if any, are to be resolved by the applicant.

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David A. Nicol, P.E.
Director, Office of Safety Design
Office of Safety

Enclosures
Illustration D-1. Drawings of Florida Concrete Curb End Treatment (14 of 14)
Illustration D-1. Drawings of Florida Concrete Curb End Treatment (9 of 14)
Illustration D-1. Drawings of Florida Concrete Curb End Treatment (6 of 14)
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**GENERAL NOTES:**

1. CONCRETE MIX:
   - F1 = 5,000 psf at 28 days.
   - F2 = 5,000 psf at 28 days.

2. CURING SHALL BE IN ACCORDANCE WITH CURRENT FLORIDA DOT STANDARDS.

3. ALTERNATIVE MATERIALS SHALL BE AS50 GRADE B OR C.

4. ALL STRUCTURAL STEEL TUBE SHALL BE AS50 GRADE B OR C.

5. ALL STRUCTURAL STEEL PIPE SHALL BE AS50 GRADE B.

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Illustration D-1. Drawings of Florida Concrete Curb End Treatment (1 of 14)
Figure 31. Summary of Results - Florida Curb End Treatment Test 71-1776-007
Figure 26. Summary of Results - Florida Curb End Treatment Test 71-1776-006
Figure 16. Summary of Results - Florida Curb End Treatment Test 71-1776-001
Figure 6. Summary of Results - Florida Curb End Treatment Test 71-1776-005
Figure 21. Summary of Results - Florida Curb End Treatment Test 71-1776-003

General Information
Test Agency: NCHRP 350 Test 2-34
Test No.: 71-1776-003
Date: 5/13/08

Test Article
Type: Concrete Curb End Treatment
Material and key elements:
- Terminal: (1) 2.4 m long Steel Segment and (1) 3.7 m Concrete Segments, Barrier: (15) 3.7 m Curb Segments
- Aged chip seal asphalt, dry

Test Vehicle
Type: Production Model
Designation: 820C
Model: 1988 Ford Festiva

Mass (kg):
- Curb: 818
- Test inertial: 832
- Dummy: 75
- Gross Static: 907

Impact Conditions
- Speed (km/h): 71.7
- Angle (deg): 15
- Impact Severity (kJ): 11.0

Exit conditions:
- Speed (km/h): 64.8
- Angle (deg - veh. c.g.): 5

Occupant Risk Values
- Impact Velocity (m/s): 1.7
- x-direction: -2.1
- y-direction: -1.7
- Ridedown Acceleration (g's): 6.0
- x-direction: -6.0
- y-direction: -6.0

European Committee for Normalization (CEN) Values
- THV (km/h): 9.8
- PHD (g's): 6.0
- ASI: 0.5

Post-Impact Vehicular Behavior (deg - rate gyro)
- Maximum Roll Angle: 33.2
- Maximum Pitch Angle: 9.2
- Maximum Yaw Angle: -24.4

Test Article Deflections (m)
- Dynamic: N/A
- Permanent: N/A

Vehicle Damage (Primary Impact)
- Exterior: N/A
- VDS: N/A
- CDC: N/A
- Interior:
  - VCDI: AS00000000
  - Maximum Deformation (mm): Negligible
Figure 11. Summary of Results - Florida Curb End Treatment Test 71-1776-002
Figure 1. Summary of Results - Florida Curb End Treatment Test 71-1776-004

General Information
Test Agency: E-TECH Testing Services, Inc.
Test Designation: NCHRP 350 Test 2-30
Test No.: 71-1776-004
Date: 5/16/08

Test Article
Type: University of Florida Concrete Curb End Treatment 6.1 m length
Installation Length: 60.9 overall with (15) curbs
Material and Key elements: Terminial: (1) 2.4 m long Steel Segment and (1) 3.7 m Concrete Segment, Barrier: (15) 3.7 m Curb Segments
Foundation Type and Condition: Aged chip seal asphalt, dry

Test Vehicle
Type: Production Model 820C
Model: 1988 Ford Festiva
Mass (kg): Curb 818, Test Inertial 832, Dummy 75, Gross Static 907

Impact Conditions
Speed (km/h): 71.0
Angle (deg): 0
Impact Severity (kJ): 161.7

Exit Conditions
Speed (km/h): 60.1
Angle (deg - veh. c.g.): 23

Occupant Risk Values
Impact Velocity (m/s):
- x-direction: 1.0
- y-direction: -0.3
Ridedown Acceleration (g's):
- x-direction: -3.9
- y-direction: 3.0

European Committee for Normalization (CEN) Values
THIV (km/h): 5.5
PHD (g's): 4.6
ASI: 0.3

Post-Impact Vehicular Behavior (deg - rate gyro)
- Maximum Roll Angle: 24.8
- Maximum Pitch Angle: 15.3
- Maximum Yaw Angle: 42.7

Test Article Deflections (m)
- Dynamic: N/A
- Permanent: N/A

Vehicle Damage (Primary Impact)
- Exterior
  - VDS: N/A
  - CDC: N/A
- Interior
  - VCDI: AS0000000
  - Maximum Deformation (mm): Negligible