



U.S. Department  
of Transportation  
**Federal Highway  
Administration**

400 Seventh St., S.W.  
Washington, D.C. 20590

November 12, 1999

Refer to: HMHS-CC60A

Mr. King K. Mak  
Research Engineer  
Texas Transportation Institute  
College Station, Texas 77843-3135

Dear Mr. Mak:

In your October 12 letter, you requested the Federal Highway Administration's (FHWA) review and approval of the specifications for the energy-absorbing composite tubes used in the Wyoming Box-Beam End Terminal (WYBET-350) that was accepted for use on the National Highway System on August 19, 1999. These specifications were developed by the Texas Transportation Institute for the Wyoming Department of Transportation, but can be used by any Department of Transportation that uses box-beam guardrail and the WYBET-350 terminal.

The specifications, which are enclosed, appear to satisfy the need for quality control of the composite tubes to ensure adequate crash performance of the WYBET-350, and we find them acceptable.

Sincerely yours,

Dwight A. Horne  
Director, Office of Highway Safety Infrastructure

Enclosure

## SPECIFICATIONS AND TEST PROCEDURE FOR COMPOSITE TUBE

This specification outlines the material properties and required energy dissipation properties for the fiberglass/epoxy composite tubes used in the Wyoming box-beam end terminal (WYBET). Two stages of energy dissipation are employed in the design: the first stage consists of a 152-mm (6-in.) diameter composite tube with a 3.2-mm (0.125-in.) wall thickness, and the second stage a 152-mm (6-in.) diameter composite tube with a 6.4-mm (0.25-in.) wall thickness.

### General Specifications

- The fiberglass/epoxy composite tube shall be manufactured using the "pultrusion" process and consists of a glass fiber reinforced resin matrix with a glass resin ratio of approximately 50 percent. The resin shall consist of isophthalic polyester and glass reinforcement shall include the following three varieties:
  - a. A surface mat shall be used on all exterior surfaces for chemical resistance and containment of other reinforcement fibers.
  - b. Continuous glass strand rovings shall be used internally for longitudinal strength.
  - c. Continuous strand mats shall be used internally for transverse strength.
- The composite material shall exhibit the following minimum mechanical properties:
  - a. Ultimate Tensile Strength:

(Longitudinal Coupon)	205 Mpa (30,000 psi)
(Transverse Coupon)	48 Mpa ( 7,000 psi)
(Full Section in Bending)	138 Mpa (20,000 psi)
  - b. Ultimate Compressive Strength:

(Longitudinal Coupon)	205 Mpa (30,000 psi)
(Transverse Coupon)	102 Mpa (15,000 psi)
(Full Section in Bending)	138 Mpa (20,000 psi)
  - c. Ultimate Shear Strength 31 Mpa ( 4,500 psi)
  - d. Ultimate Breaking Strength 205 Mpa (30,000 psi)
  - e. Modulus of Elasticity  
(Full Beam Section in Bending) 17237 Mpa (2.5 x 10<sup>6</sup> psi)
  - f. Barcol Hardness 50

## Crash Force Characteristics

- The energy dissipation properties of the composite tube shall be evaluated using static compressive testing. The composite tubes shall have the following static energy dissipation properties:

First stage composite tube -- 152-mm (6-in.) diameter with 3.2-mm (0.125-in.) wall thickness

Average Crush Force, $F_c$	85 ± 13 kN (19 ± 3 kips)
Maximum Compressive Force, P	116 kN (26 kips)

Second stage composite tube -- 152-mm (6-in.) diameter with 6.4-mm (0.25-in.) wall thickness

Average Crush Force, $F_c$	178 ± 18 kN (40 ± 4 kips)
Maximum Compressive Force, P	245 kN (55 kips)

Definitions of the average crush force,  $F_c$ , and maximum compressive force, P, are illustrated in the following figure. The average crush force shall be determined based on crush forces from 152 mm to 355 mm (6.0 in. to 14.0 in.) of crush. The maximum compressive force shall be determined between 90 mm to 152 mm (3.5 in. to 6.0 in.) of crush.

## Acceptance/Rejection Criteria

- The acceptance/rejection criteria will be based on the crush force characteristics, i.e., average crush force,  $F_c$ , and maximum compressive force, P. The properties outlined in the "General Specifications" are provided for information purposes and are not considered in the acceptance/rejection criteria.
- A minimum of three (3) static compressive tests should be conducted at an independent testing laboratory. The three samples shall be randomly selected, one each from the beginning, middle and end of the production run being evaluated. Each test specimen shall be 610 mm (24 in.) long and a 100 mm (4 in.) long tulip shape shall be cut into one end of the test specimen. End caps shall be used with the specimen on both ends.

The test specimen shall be crushed statically at a rate of 50 mm (2 in.) per minute and the total crush length or displacement shall be no less than 355 mm (14.0 in.).

- The batch is considered acceptable if the following conditions are met:
  1. The average crush force characteristics for the three specimens are within the acceptable ranges as specified above and repeated below:

First stage composite tube -- 152-mm (6-in.) diameter with 3.2-mm (0.125-in.) wall thickness

Average Crush Force, $F_c$	85 ± 13 kN (19 ± 3 kips)
Maximum Compressive Force, $P$	116 kN (26 kips)

Second stage composite tube -- 152-mm (6-in.) diameter with 6.4-mm (0.25-in.) wall thickness

Average Crush Force, $F_c$	178 ± 18 kN (40 ± 4 kips)
Maximum Compressive Force, $P$	245 kN (55 kips)

2. The crush force characteristics for each of the three specimens do not exceed the acceptable ranges by more than 10 percent. In other words, each specimen shall not exceed the following static energy dissipation properties:

First stage composite tube -- 152-mm (6-in.) diameter with 3.2-mm (0.125-in.) wall thickness

Average Crush Force, $F_c$	85 ± 22 kN (19 ± 5 kips)
Maximum Compressive Force, $P$	127 kN (28.5 kips)

Second stage composite tube -- 152-mm (6-in.) diameter with 6.4-mm (0.25-in.) wall thickness

Average Crush Force, $F_c$	178 ± 36 kN (40 ± 8 kips)
Maximum Compressive Force, $P$	267 kN (60 kips)

# Static Crush Test Pultruded Fiber-Glass Tube

