

December 13, 2002

MEMORANDUM

TO: All Users of the Florida Department of Transportation
Structures Design Guidelines

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SUBJECT: **Temporary Design Bulletin C02-18**
FDOT Structures Design Guidelines Topic No. 625-020-154-b
Chapter 6 Structures Design Guidelines (LRFD)

Section 6.4 of the August 2002 release of the Structures Design Guidelines is hereby deleted and the following inserted:

6.4 Traffic Railings [13.7]

6.4.1 General Requirements

Unless otherwise approved, all new bridge, approach slab and retaining wall mounted traffic railings and end treatments proposed for use in new construction, rehabilitation, reconstruction, and widening projects, as well as all traffic railings and end treatments proposed as retrofits for existing traffic railings, shall be proven effective through successful crash testing. Crash testing shall be performed in accordance with, and comply with, the **National Cooperative Highway Research Program (NCHRP) Report 350** and the AASHTO **LRFD Bridge Design Specifications**. This requirement also applies to traffic railing and sound barrier combinations and traffic railing and glare screen combinations.

In addition to the preceding criteria, all bridge, approach slab and retaining wall mounted traffic railings shall:

- A. Be structurally evaluated to be equivalent to or greater in strength to other traffic railings that have been crash tested to the TL-4 (minimum), TL-5 or TL-6 criteria (as appropriate) of **NCHRP Report 350**.
- B. Meet the strength and geometric requirements of *LRFD* Section 13 in accordance with the test levels and crash test criteria.
- C. Be upgraded on both sides of a structure when widening work is proposed for only one side and the traffic railing on the non-widened side does not meet the criteria for new traffic railings (See Section 6.4.3).
- D. For new construction, be constructed on decks reinforced in accordance with Chapter 7. See Section 6.4.3 for deck requirements for traffic railing retrofits on existing bridges.

The traffic railings shown on the **Structures Standard Drawings**, Index Nos. 700 through 780 Series, have been determined to meet the applicable crash testing requirements. The applicability of each of these standard traffic railings is addressed in the **Plans Preparation Manual, Volume I**. These standard traffic railings are preferred for use on structures in Florida.

The use of a non-FDOT standard or new bridge traffic railing requires the prior approval of the Structures Design Office. Proposed modifications to standard traffic railings also require prior Structures Design Office approval. Such proposed modifications may include but are not limited to reinforcement details, surface treatments, material substitutions, geometric discontinuities, end transition details and traffic face geometry. A non-FDOT standard or new bridge traffic railing type can be approved for use on Florida bridges by the Structures Design Office in any one of the following ways:

- It has been successfully crash tested in accordance with **NCHRP Report 350** criteria to a minimum of Test Level 4.
- It has been approved for specific uses by FHWA after evaluation of results from successful crash testing based on criteria that predate **NCHRP Report 350** Test Level 4.
- It has been evaluated by FDOT and identified as similar in strength and geometry to another railing that has been successfully crash tested in accordance with **NCHRP Report 350** Test Level 4 criteria.

The background for this policy is based on the Test Level Selection Criteria as defined in Section 13 of the AASHTO **LRFD Bridge Design Specifications** and on historical

construction costs and in-service performance of standard FDOT TL-4 traffic railings. This background can be summarized as follows:

- In general, a greater potential exists for overtopping or penetrating a shorter height, lower test level traffic railing versus a similarly shaped TL-4 traffic railing. This potential is further aggravated on tall bridges and on bridges over intersecting roadways or water deep enough to submerge an errant vehicle. Vehicle performance during higher speed impacts is also more critical on lower test level traffic railings.
- Little construction cost savings can be realized by using a lower test level traffic railing. In some cases, particularly with the more elaborate or ornate traffic railing designs, initial construction costs and long term repair and maintenance costs could actually be greater than those for a standard FDOT TL-4 design.
- Aesthetically pleasing and open TL-4 traffic railing designs are available for use on bridges where appropriate.
- On bridges with sidewalks where special aesthetic treatments are desired or required, the use of an aesthetic pedestrian railing located behind a TL-4 traffic railing is a more appropriate solution. For this type of a design, the aesthetics of the traffic railing should be considered to avoid a conflict with the aesthetics of the pedestrian railing.

For more detailed information on Florida bridge traffic railings, refer to the **Structures Standard Drawings**. For additional information about crash-tested bridge traffic railings currently available or about bridge traffic railings currently under design or evaluation, contact the Structures Design Office.

6.4.2 FHWA Policy on Bridge Traffic Railing

Since September 1, 1986, the Federal Highway Administration (FHWA) has required highway bridges on the National Highway System (NHS) and the Interstate Highway System to have crash-tested railing. Current policy is stated in the following documents:

1. Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA).
<http://www.fhwa.dot.gov/legsregs/legislat.html>

Requires that measures to enhance the crashworthiness of roadside features accommodate vans, minivans, pickup trucks, and 4-wheel drive vehicles, as well as cars.

2. **National Cooperative Highway Research Program (NCHRP) Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features.**

http://safety.fhwa.dot.gov/programs/roadside_hardware.htm

Provides guidance for testing highway features to assess safety performance of those features. Guidance includes definitions of crash-test levels with specified vehicle, speed, and impact angle for each level.

3. May 30, 1997, memorandum from Dwight Horne on the subject of "Crash Testing of Bridge Railings".

<http://safety.fhwa.dot.gov/fourthlevel/hardware/pdf/bridge.pdf>

Identifies 68 crash-tested bridge rails, consolidating earlier listings and establishing tentative equivalency ratings that relate previous testing to **NCHRP Report 350** test levels.

4. July 25, 1997, memorandum from Donald Steinke on the subject of "Identifying Acceptable Highway Safety Features".

<http://www.fhwa.dot.gov/legsregs/directives/policy/ra.htm>

Clarifies and summarizes policies on bridge traffic railing, points to authorities for requiring testing of bridge traffic railing, and identifies methods for submitting new rails for testing. This document also identifies exceptions, one of which is the replacement or retrofitting of existing bridge traffic railing unless improvements are being made on a stretch of highway that includes a bridge with obsolete railing.

On its web site, FHWA provides current information on three general categories of roadside hardware that are tested and evaluated using **NCHRP Report 350** criteria; one of those categories is Bridge Railing:

<http://safety.fhwa.dot.gov/fourthlevel/hardware/bridgerailings.htm>

6.4.3 Existing Bridges with Obsolete Traffic Railings

A. General Requirements

FDOT promotes highway planning that replaces or upgrades non-crash tested traffic railing on existing bridges to current standards, or that at least increases the strength or expected crash performance of these traffic railings. FDOT has developed two sets of

Structures Standards, the Index 770 and 780 Series, for retrofitting existing bridges with traffic railing types that have performed well in crash tests and are reasonably economic to install. Detailed instructions and procedures for retrofitting obsolete traffic railings on existing bridges are included in the **Structures Standard Drawings**.

When rehabilitation work is proposed on an existing bridge with traffic railings that do not meet the criteria for new railings as provided in Section 6.4.1, the existing traffic railings shall be replaced or retrofitted to meet the crash-worthy criteria unless an exception is processed. Refer to Chapter 23 of the **Plans Preparation Manual, Volume 1** for information about exceptions.

B. FHWA Policy on Existing Traffic Railings

The Federal Highway Administration (FHWA) requires that bridge railing on the National Highway System (NHS) meet requirements of **NCHRP Report 350**:

“...all new or replacement safety features on the NHS covered by the guidelines in the **NCHRP Report 350** that are included in projects advertised for bids or are included in work done by force-account or by State forces on or after October 1, 1998, are to have been tested and evaluated and found acceptable in accordance with the guidelines in the **NCHRP Report 350**” (See Section 6.4.2, Number 4).

However, FHWA softens this requirement somewhat by allowing exceptions:

“Bridge railings tested and found acceptable under other guidelines may be acceptable for use on the NHS.” This is a specific reference to the Horne memo titled “Crash Testing of Bridge Railings” (See Section 6.4.2, Number 2).

“The FHWA does not intend that this requirement (that new safety features installed on the NHS be proven crashworthy in accordance with the guidelines in the **NCHRP Report 350**) result in the replacement or upgrading of any existing installed features beyond what would normally occur with planned highway improvements.”

This statement is qualified by a requirement that states have a “rational, documented policy for determining when an existing non-standard feature should be upgraded.”

C. Traffic Railing Retrofit Concepts and Standards

Existing non-crash tested traffic railings designed in accordance with past editions of the AASHTO and AASHTO **Standard Specifications for Highway Bridges** will likely not meet current crash test requirements and will also likely not meet the strength and height requirements of the AASHTO **LRFD Bridge Design Specifications**. The retrofitting of these existing non-crash tested traffic railings reduces the separate but related potentials for vehicle snagging, vaulting and / or penetration that can be associated with many obsolete, non-crash tested designs.

The Thrie Beam Guardrail Retrofit and Vertical Face Retrofit Structures Standards, Index 770 and 780 Series, respectively, are suitable for retrofitting specific types of obsolete bridge traffic railings. These retrofits provide a more economical solution for upgrading obsolete traffic railings when compared with replacing the obsolete traffic railings and portions of the bridge decks that support them. As these retrofits do not provide for any increase in clear width of bridge deck, and in a few cases decrease clear width by approximately 2 inches, they should only be considered for use on existing bridges where adequate lane and shoulder widths are present. Detailed guidance and instructions on the use of these retrofits is included in the individual Structures Standards.

As part of the planning for a bridge that will be widened or rehabilitated, or for a bridge that is located within the limits of a 3R project, consider the following aspects of the project in the selection of a retrofit railing:

- Elements of the bridge structure
- Characteristics of the bridge location
- Features of the retrofit designs

Evaluate the effect of a retrofit on the shoulder width of the bridge to ensure that a reduction in effective shoulder width (if applicable) or in sight distances at adjacent intersections will not increase the accident rate. Also consider the following:

- Bridge width, alignment and grade
- Type, aesthetics, and strength of existing railing
- Bridge length and its potential for posting speed limits

Evaluate details of the location, such as the following, and consider their effect on selection of a retrofit railing:

- Bridge structure's height above lower terrain or waterway
- Approach roadway's width, alignment and grade
- Position of adjacent streets and their average daily traffic
- Bridge design speed, posted speed, average daily traffic and percentage of truck traffic
- Accident history on the bridge

Carefully review details of potential retrofit designs, such as the following, and consider their effect on selection of a retrofit railing:

- Placement or spacing of anchor bolts or dowels
- Reinforcement anchorage and potential conflicts with existing reinforcement, voids, etc.
- Approach and trailing end treatments (guardrail, crash cushion or rigid shoulder barrier)
- MOT required for initial construction of retrofit and for potential future repairs
- Self weight of retrofit railing
- Strength of supporting deck configuration
- Load rating of existing bridge

D. Evaluation of Existing Supporting Structure Strength for Traffic Railing Retrofits

The Thrie Beam Guardrail and Vertical Face traffic railing retrofits are based on designs that have been successfully crash tested in accordance with **NCHRP Report 350** to Test Level 4 or have been previously crash tested and then accepted at Test Level 4. The original designs have been modified for use with some of the wide variety of traffic railings and supporting deck and wing wall configurations that were historically constructed on Florida bridges. In recognition of the fact that the traffic railings and supporting decks and wing walls of these existing bridges were designed to meet the less demanding requirements of past AASHTO and AASHTO Bridge Codes, modifications have been made to the original retrofit designs in order to provide for better distribution of vehicle impact force through the traffic railing retrofit and into the supporting bridge deck or wing wall. For Thrie Beam Guardrail Retrofit installations on narrow curbs and or lightly reinforced decks, a smaller post spacing is used. In addition, through-bolted anchors are used for some Thrie Beam Guardrail Retrofit installations. For the Vertical Face Retrofit, additional longitudinal reinforcing steel and dowel bars at the open joints are used within the new

railing.

Existing bridge decks, wing walls and retaining walls that will support a traffic railing retrofit must be evaluated to determine if sufficient strength is available to ensure that the retrofit will perform in a manner equivalent to that demonstrated by crash testing. Existing bridges may contain Grade 33 reinforcing steel if constructed prior to 1952 or Grade 40 reinforcing steel if constructed prior to 1972. Use 90% of the ultimate tensile strength of these materials when determining the existing capacity for combined tension and moment from traffic railing impacts ($f_s = 49.5$ ksi for Grade 33, $f_s = 63$ ksi for Grade 40). For bridges with varying spacings and sizes of transverse reinforcing steel in the deck or curb, the average area of transverse steel for the span may be used.

Existing cast-in-place reinforced concrete bridge decks shall be analyzed at a section through the deck at the gutter line for the appropriate FDOT traffic railing retrofit Standard Indexes using the following design values:

<u>Traffic Railing Type</u>	<u>Standard Index No.</u>	<u>M_g</u>	<u>T_u</u>
Thrie-Beam Retrofit	Nos. 772, 776 & 777	5.8	4.7
Thrie-Beam Retrofit	Nos. 773 & 774	8.3	6.7
Thrie-Beam Retrofit	No. 775	9.7	7.9
Vertical-Face Retrofit	Nos. 782-785	12.9	7.5

M_g (kip-ft/ft) - Ultimate deck moment at the gutter line from the traffic railing impact.

T_u (kip/ft) - Total ultimate tensile force to be resisted.

The following relationship must be satisfied at the gutter line:

$$\frac{T_u}{\phi P_n} + \frac{M_u}{\phi M_n} \leq 1.0 \quad (\text{Eq. 6-1})$$

Where:

$$\phi = 1.0$$

$P_n = A_s f_s$ (kips/ft) - Nominal tensile capacity based on the areas of transverse reinforcing steel in both the top and bottom layers of the deck (A_s). This reinforcing steel must be fully developed at the critical section through the deck at the gutter line.

M_u (kip-ft/ft) - Total ultimate deck moment from traffic railing impact and factored dead load at the gutter line ($M_g + 1.25 * M_{\text{Dead Load}}$).

M_n (kip-ft/ft) - Nominal moment capacity at the gutter line determined by traditional rational methods for reinforced concrete. The bottom layer of steel shall not be included unless a strain compatibility analysis is performed to determine the steel stress in this layer with the compressive strain in the concrete limited to 0.003.

Decks constructed of longitudinally prestressed, transversely post-tensioned voided or solid slab units generally only contain minimal transverse reinforcing ties. Retrofitting bridges with this type of deck will not be permitted after January 1, 2010. For these type bridges, the strength checks of the deck at the gutter line will not be required. Only Index No. 776 or Index 780 Series retrofits can be used to retrofit these bridges.

In addition to checking the existing deck capacity at the gutter line, the following minimum areas of reinforcing steel per longitudinal foot of span must also be satisfied unless a more refined analysis is performed to justify a lesser area of steel at these locations:

<u>Location of Reinforcing Steel</u>	<u>Min. Area Steel (in²/ft) for Standard Index</u>			
	<u>Nos. 772, 776 & 777</u>	<u>Nos. 773 & 774</u>	<u>No. 775</u>	<u>780 Series</u>
Transverse in top of curb beneath post:				
- Grade 33 reinforcing	0.32	0.40	0.40	N/A
- Grade 40 & 60 reinforcing	0.25	0.31	0.31	N/A
Vertical in front face of curb for thickness "D":				
- Grade 33 reinforcing	0.20	2.25/(D-2)**	2.65/(D-2)**	3.30/(D-2)**
- Grade 40 & 60 reinforcing	0.20*	1.80/(D-2)**	2.10/(D-2)**	2.60/(D-2)**

* 0.16 in²/ft is acceptable for $D \geq 15$ inches.

** Minimum area of reinforcing steel must not be less than 0.16 in²/ft.

Where:

D (inches) = Horizontal thickness of the curb at the gutter line.

If the minimum areas of reinforcing in the curb given above are not satisfied, the following design values may be used for a refined analysis of the existing curb beneath the post for the Index 770 Series retrofits:

<u>Traffic Railing Type</u>	<u>Standard Index No.</u>	<u>M_p</u>	<u>T_u</u>
Thrie-Beam Retrofit	Nos. 772, 776 & 777	9.7	7.9
Thrie-Beam Retrofit	Nos. 773, 774 & 775	12.0	9.9

M_p (kip-ft/ft) - Ultimate deck moment in the curb at centerline of post from the traffic railing impact.

T_u (kip/ft) - Total ultimate tensile force to be resisted.

The following relationship must be satisfied in the curb at centerline of post:

$$\frac{T_u}{\phi P_n} + \frac{M_u}{\phi M_n} \leq 1.0 \quad (\text{Eq. 6-2})$$

Where:

$$\phi = 1.0$$

P_n = A_sf_s (kips/ft) - Nominal tensile capacity based on the areas of transverse reinforcing steel in both the top and bottom of the curb (A_s). This reinforcing steel must be fully developed at the critical section.

M_u (kip-ft/ft) - Total ultimate moment in the curb from traffic railing impact and factored dead load at centerline of post (M_p + 1.25*M_{Dead Load}).

M_n (kip-ft/ft) - Nominal moment capacity of the curb at centerline of post determined by traditional rational methods for reinforced concrete. The bottom layer of steel in the curb shall not be included unless a strain compatibility analysis is performed to determine the steel stress in this layer with the compressive strain in the concrete limited to 0.003.

The ultimate moment capacity of existing wing walls and retaining walls supporting the traffic railing retrofits must not be less than 9.7 kip-ft/ft for Index 770 Series retrofits and 12.0 kip-ft/ft for Index 780 Series retrofits. Wing walls for Index 780 Series retrofits must also be a minimum of 5 feet in length and pile supported. For Index 780 Series retrofits only, wing walls that do not meet these criteria must not be used to anchor the ends of

guardrail transitions and must be shielded by continuous guardrail as shown on the **Structures Standard Drawings**. For both 770 and 780 Series retrofits, retaining walls must be continuous without joints for a minimum length of 10 feet and adequately supported to resist overturning.

An exception will be required for bridges or components of bridges that do not meet the preceding strength requirements. The potential for damage to the existing bridge deck or wing walls due to a very severe crash, such as that modeled by full scale crash testing, may be acceptable in specific cases. Contact the Structures Design Office for additional guidance and assistance in these cases.

6.4.4 Traffic Railings for Historic Bridges

Federal law protects historically significant bridges, and any project involving their rehabilitation or improvement requires special attention. The Director of the Division of Historical Resources of the Florida Department of State serves as Florida's State Historic Preservation Officer (SHPO). The SHPO and FDOT are responsible for determining what effect any proposed project will have on a historic bridge.

Bridges that are designated historic and that are listed or eligible to be listed in the National Register of Historic Places introduce a special railing challenge because the appearance of the bridge may be protected even though the historic railing may not meet current standards. As soon as a project is determined to involve a historically significant bridge, the District should contact the Structures Design Office for assistance with evaluating the existing bridge railings.

Original railing on a historic bridge is likely not to meet current crash test requirements. It also is likely not to meet current standards for railing height (a minimum of 32 inches for Test Level 4) and for combination traffic and pedestrian railings, the limits on the size of openings in the railing (small enough that a 6 inch diameter sphere cannot pass through them per the AASHTO **LRFD Bridge Design Specifications**). Options for upgrading the railing on historic bridges usually include the following:

- Place an approved traffic railing inboard of the existing railing, leaving the existing railing in place. This is sometimes appropriate when a pedestrian walkway exists on or is planned for the bridge.
- Replace the existing railing with an approved, acceptable railing of similar appearance.

- Remove the current railing and incorporate it into a new acceptable railing. This may be appropriate in rare instances where an existing railing is especially decorative.
- Design a special railing to match the appearance of the existing railing. It may not be necessary to crash test the new railing if the geometry and calculated strength equal or exceed a crash tested traffic railing.

6.4.5 Requirements for Test Levels 5 and 6 [13.7.2]

Consideration should be given to providing a traffic railing that meets the requirements of Test Levels 5 or 6 (TL-5 or TL-6) as included in **NCHRP Report 350** when any of the following conditions exist:

- A. The volume of truck traffic is unusually high.
- B. The proposed structure is located such that a vehicle penetrating or overtopping the traffic railing would cause high risk to the public or surrounding facilities.
- C. Sharply curved ramp structures with moderate to heavy truck traffic.

Contact the Structures Design Office for further guidance if a TL-5 or TL-6 traffic railing is being considered for use.

6.4.6 Exceptions

Rarely, but occasionally, an upgrade to the traffic railing on an existing bridge could degrade rather than improve bridge safety. The Structures Design Office should be consulted about a possible design exception during the early phases of a project if replacing or retrofitting an existing traffic railing in order to meet current standards will reduce overall safety. Factors to consider include the following:

- Remaining time until scheduled replacement or major rehabilitation of bridge
- Design speed and operating speed of traffic in the bridge location, preferably no greater than 45 mph
- Resistance to impact of the existing railing
- Whether the bridge ends are intersections protected by stop signs or traffic signals
- Whether the geometry is straight into, along and out of the bridge
- Overall length of the bridge
- Whether traffic on the bridge is one-way or two-way
- Accident history on the bridge, including damages to and repairs of the existing railing
- Risk of fall over the side of the bridge
- Whether the bridge has an intersecting roadway or railroad track below

- Whether a railing upgrade will further narrow an already narrow lane, shoulder or sidewalk
- Load rating of the existing bridge
- Special historic or aesthetic concerns

Exceptions to the requirements of this Article shall be processed in accordance with Chapter 23 of the ***Plans Preparation Manual, Volume I***.

6.4.7 Sound Barriers

Sound barriers shall not be attached to the top of traffic railings unless the system has been crash tested and meets TL-4 acceptability requirements of ***NCHRP Report 350***. Non-crash tested sound barriers may be attached to structures if located behind an approved traffic railing and mounted at least five feet from the face of the traffic railing at deck level. The Traffic Railing Barrier/Soundwall, Structures Standard Index No. 1550, is crash tested and approved for TL-4 use on Florida bridges.