INTEROFFICE MEMORANDUM

DATE: March 23, 2005

TO: Mr. Phillip McConnell, Assistant Chief Engineer for Design

FROM: Phil Brand, Bridge Engineer CPB

SUBJECT: Median Rail at Overhead Sign Supports

Recently, we have been investigating current design code requirements for protection of overhead sign structural supports placed within the clear zone and that are not protected by barrier or guardrail. The AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, 4th Edition, does not address the design of the sign supports for these circumstances.

The situation of particular interest to us is that which occurs at the concrete median barrier of divided highways where, depending upon the height of the barrier, the metal sign support may be vulnerable to vehicular impact. While it is intuitive that a barrier that is sufficiently tall is similar to a wall in that it is nearly impossible for any part of a vehicle to reach the top of the barrier and impact the support, the determination of a 'sufficiently tall' height is less intuitive, and is the purpose of this memorandum.

As discussed in the AASHTO Roadside Design Guide (6.4.1.7), passenger vehicles may become partially airborne and reach the top of safety shaped barriers 42" or shorter during high-angle, high-speed impacts. Vehicles with a high center of gravity, such as large trucks, may lean or roll toward the barrier during impact at even shallow angles, and the top portion of the cargo box may then contact fixed objects on top of or immediately behind the barrier, such as sign supports. Also noted is that a "Vertical concrete barrier wall can be an effective alternative to the wider safety shape barriers… ."

The AASHTO LRFD Bridge Design Specifications (C3.6.5.1) further notes, "Full-scale crash tests have shown that some vehicles have a greater tendency to lean over or partially cross over a 42" high barrier than a 54" high barrier. This behavior would allow a significant collision of the vehicle with the component being protected if the component is located within a few feet of the barrier".

Reference is also made to the attached MEMO TO THE FILE dated February 8, 2005. As part of this documentation for Job No. R60042, the FHWA gives a favorable opinion to the vertical face barrier concept.

With the above as a basis, we propose that a minimum concrete barrier height of 54" be used when a sign support is placed on top of it. Further, we recommend that this height barrier extend a minimum of 25' either side of the sign support, and that it have a vertical face throughout this length. This length would seem to reduce the risk that the attitude of an impacting vehicle will

Concur 4-11-05 PLM

be such that it can strike the sign support. A transition in height or shape to the typical barrier section would occur outside this length.

We believe this recommendation will result in an improved level of safety for the traveling public, and will reduce the occurrences, as well as the severity, of a vehicle striking the support. Your approval or comments is requested.

CPB/mah
Attachments

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mm (18 in). Research suggests that a breakaway support should not be located where the trajectory of an errant vehicle is likely to result in the bumper of the vehicle striking the support more than 700 mm (28 in) above the ground line at the support. This criterion will be met where a foreslope is no greater than 1 to 6 or the face of the support is not more than 600 mm (24 in) outside the intersection of a shoulder slope and a 1 to 4 foreslope.

2.5.3 Guardrails and Other Barriers

The location of roadside sign and luminaire supports behind a guardrail should provide clearance between the back of the rail and the face of the support to insure that the rail will deflect properly when struck by a vehicle. Continuity of the railing on rigid highway structures should not be interrupted by sign or luminaire supports.

Guardrails, as illustrated in Figure 2–1, are provided to shield motorists from fixed objects and to protect fixed objects, such as overhead sign supports. The *Roadside Design Guide* provides guidelines for the provision of roadside barriers for fixed objects.

The clearance between the edge of a sign panel, which could present a hazard if struck, and the back of a barrier should also take into consideration the deflection of the rail. The edge of a sign shall not extend inside the face of the railing.

The clearance between the back of the barrier and the face of the support may vary, depending on type of barrier system utilized. The *Roadside Design Guide* may be used to determine the proper clearance.

2.5.4 Roadside Sign and Luminaire Supports

Roadside sign and typical luminaire supports, within the clear zone distance specified in Article 2.5.1, should be designed with a breakaway feature acceptable under NCHRP Report 350, or protected with a guardrail or other barrier. Where viewing conditions are favorable, roadside sign and typical luminaire supports may be placed outside the clear zone distance.

Where there is a probability of being struck by errant vehicles, even supports outside this suggested clear zone should preferably be breakaway.

2.5.5 Overhead Sign Supports and High-Level Lighting Supports

Overhead sign and high-level lighting structural supports should be placed outside the clear zone distance; otherwise, they should be protected with a proper guardrail or other barrier.

Overhead sign and high-level lighting supports are considered fixed-base support systems that do not yield or break away upon impact. The large mass of these support systems and the potential safety consequences of the systems falling to the ground necessitate a fixed-based design. Fixed-base systems are rigid obstacles and should not be used in the clear zone area unless shielded by a barrier. In some cases, it may be cost effective to place overhead sign supports outside the clear zone with no barrier protection when the added cost of the greater span structure is compared to the long-term costs of guardrail and

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vegetation maintenance. Some structures can sometimes be located in combination with traffic barriers protecting other hazards such as culverts, bridge ends, and embankments.

2.5.6 Traffic Signal Supports

Traffic signal supports that are installed on high-speed facilities should be placed as far away from the roadway as practical. Shielding these supports should be considered if they are within the clear zone for that particular roadway.

Traffic signal structural supports with mast arms or span wires normally are not provided with a breakaway device. However, pedestal pole traffic signal supports are appropriately designed to be breakaway. Pedestal poles should, if possible, be placed on breakaway supports because they are usually in close proximity to traffic lanes.

2.5.7 Gores

Where obstruction in the gore is unavoidable within the clear zone, protection should be provided by an adequate crash cushion or the structure should be provided with a breakaway device.

2.5.8 Urban Areas

For sign, luminaire, and traffic signal structures located in working urban areas, the minimum lateral clearance from a barrier curb to the support is 500 mm (20 in). Where no curb exists, the horizontal clearance to the support should be as much as reasonably possible.

The 500 mm offset is not an urban *clear zone,* rather it was established to avoid interference with truck mirrors, open doors, and so forth. The preferred location of support structures is on the *house side* of the sidewalk.

2.5.9 Joint-Use Supports

Where possible, consideration should be given to the joint usage of supports in urban areas.

Advantage should be taken of joint usage to reduce the number of supports in urban areas. For example, a traffic sign and signal support can be combined with a lighting pole.

2.6 CORRELATION OF STRUCTURAL SUPPORT DESIGN WITH ROADWAY AND BRIDGE DESIGN

2.6.1 Signs

Sign panels may be supported on existing or proposed grade separation structures. In these cases, the minimum vertical clearance requirements for overhead signs do not apply. A specifically designed frame shall be required to attach the sign panel to the existing structure. The overhead sign should be located as near to the most

Sign installation on grade separation structures is generally acceptable aesthetically when the sign panels do not extend below the girders or above the railing. The sign panel should be placed slightly above the minimum vertical clearance specified for the grade separation structure. Close liaison between bridge and traffic engineers is es-

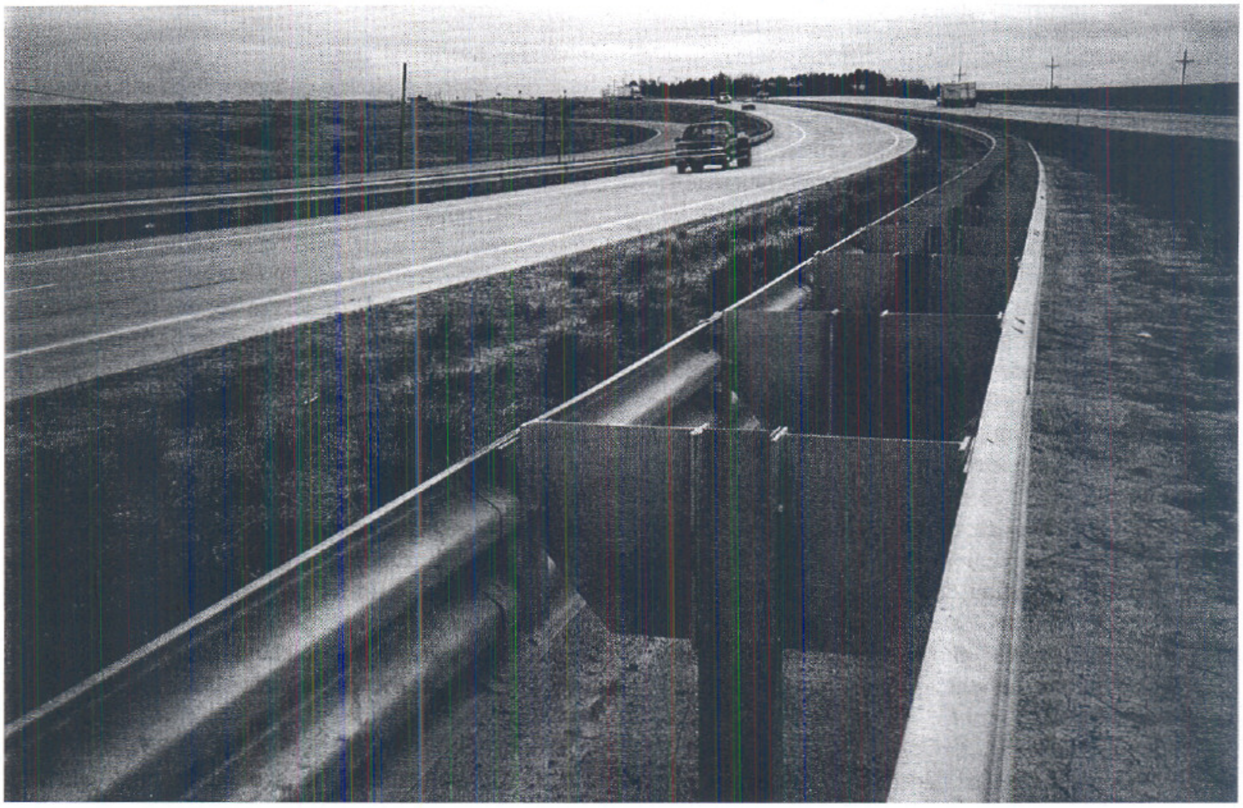

FIGURE 6.6 Modified thrie-beam median barrier

median barrier design are considered to be TL-4 longitudinal barriers. The modified thrie-beam median barrier is shown in Figure 6.6.

6.4.1.7 Concrete Barrier

Concrete barrier is the most common rigid median barrier in use today. Its popularity is based on its relatively low life-cycle cost, generally effective performance, and its maintenance-free characteristics. Concrete barrier designs vary in shape, construction type, and reinforcement.

Research has shown that variations in the face of the concrete barrier can have a significant effect on barrier performance (5). Concrete barrier shapes that meet the NCHRP Report 350 criteria are the New Jersey and F-shapes, the single slope barrier (two variations in slope), and the vertical wall. These shapes when adequately designed and reinforced may all be considered TL-4 designs at the standard height of 810 mm [32 in.] and TL-5 designs at heights of 1070 mm [42 in.] and higher.

The New Jersey shape and F-shape barriers are commonly referred to as "safety shapes." Figure C.6, Appendix C, compares dimensions of these two barriers. The critical variable is the height above the road surface of the break between the upper and lower slope. If this break is higher than 330 mm [13 in.], the chances of a vehicle overturning are increased, particularly for compact and subcompact automobiles. Although both shapes are effective in safely redirecting impacting vehicles, research indicates that the F-shape, which has the slope break at 250 mm [10 in.], may perform better for small vehicles with respect to vehicle roll than the New Jersey shape.

The basic New Jersey and F-shape have an overall height of 810 mm [32 in.]; this includes provision for a 75 mm [3 in.] future pavement overlay, reducing the height to 735 mm [29 in.] minimum. When total overlay depths are expected to exceed 75 mm [3 in.] or when an 810 mm [32 in.] height is considered inadequate, the total height of the concrete must be adjusted. This adjustment must be made above the slope breakpoint. The height extension may follow the slope of the upper face if the barrier is thick enough or adequately reinforced at the top, or the extension may be vertical. A height extension may also be considered for use as a screen to block headlight glare from opposing traffic lanes.

There are two important factors related to safety-shaped concrete median barriers that are important to note. For high-angle, high-speed impacts, passenger size vehicles may become partially airborne and in some cases may reach the top of the barrier. Fixed objects, e.g., luminaire supports, on top of the wall may cause snagging or separate from the barrier and fly into opposing traffic lanes. New York State has designed and tested a box-beam retrofit that is installed near the top of the upper face of the barrier to limit vehicle climb and to improve performance under these conditions.

The second factor to consider is that, even for shallow angle impacts, the roll angle toward the barrier imparted to high-center-of-gravity vehicles may be enough to permit contact by the top portion of the cargo box with fixed objects on top of or immediately behind the wall. Bridge piers are one of the common obstacles typically shielded by a concrete safety shape. Unless the barrier is significantly higher than 810 mm [32 in.] or modified as noted above, a bus or tractor trailer is likely to lean enough to strike the pier even though it does not penetrate the barrier. Even the 1070 mm [42 in.] high concrete safety shapes shown in Figures C.7 and C.8, Appendix C, produced significant roll when struck by a 36000 kg [80,000 lb] combination truck at an impact angle of 15 degrees and 80 km/h [50 mph]. This so-called "Tall Wall" barrier is classified as a high-performance barrier. It has been successfully used for many years by the New Jersey Turnpike Authority in its reinforced version and in Ontario without reinforcement (6).

Single slope concrete barriers have been developed and tested (7). Slopes of 9.1 degrees and 10.8 degrees have been used successfully on these barriers. The primary advantage of this barrier shape is that the pavement adjacent to it can be overlaid several times without affecting the performance of the barrier. The original height of 1070 mm [42 in.] may thus be reduced to 760 mm [30 in.].

Vertical concrete barrier wall can be an effective alternative to the wider safety-shape barriers and can preserve available median shoulder width at narrow locations such as in front of bridge piers. Vehicle damage in crashes with a vertical wall is greater than with safety-shaped barriers, but injuries are comparable and the preservation of shoulder width is a safety benefit.

Many variations exist between highway agencies regarding reinforcing and footing details for concrete median barriers; however, there have been few reported problems with any particular design and a need (or desirability) for a standard detail is not apparent. Research by the California Department of Transportation has shown that a concrete footing is not necessary; the concrete can be cast directly on asphaltic concrete, Portland cement concrete, or a well-compacted aggregate base (8). This research also revealed no adverse effects to barrier performance when contraction joints were left to form uncontrolled in lightly reinforced concrete. Longitudinal reinforcement in the upper portion of the barrier stem serves to control the size and scatter of concrete fragments that may occur as a result of severe barrier impacts. Several states use non-reinforced concrete barrier. Shrinkage cracks of up to 20 mm [$^3/_4$ in.] have not affected the operational strength of concrete barriers, and no breakouts have been experienced where the top width is at least 300 mm [12 in.]. In general, if the in-service performance of a State's concrete barrier design reflects desired results, that design may be considered acceptable.

Concrete median barrier may be slip-formed, precast, or cast-in-place. Slip-formed barriers are cost-effective where long lengths of barrier can be placed without interruption. Equipment is available to slip-form barriers to a variable height where necessary to fit a stepped-median cross section and where the elevations of adjacent roadways do not vary by more than 0.9 m [3 ft]. Precast construction is sometimes used as an alternate to slip-formed barrier and is frequently used where split median barriers are needed to shield objects such as bridge piers or overhead sign supports. Precast concrete barrier sections can be embedded in or anchored to the pavement to form a rigid barrier. However, several states use an unanchored precast concrete barrier for permanent installations. The unanchored barrier deflects when impacted, reducing the force of impact as compared to a rigid barrier. The deflected barrier requires repositioning, but the effort is less than the repair of any other semi-rigid barrier system. Cast-in-place construction is the most versatile method because forming can be varied to fit non-typical situations.

Examples of concrete median barriers are shown in Figures 6.7 and 6.8.

6.4.1.8 Quickchange® Moveable Barrier System

This proprietary portable barrier system, shown in Figure 6.9, is composed of a chain of modified F-shape concrete barrier segments 940 mm [37 in.] in length that can be readily shifted laterally. Steel rods run the length of each segment, and specially designed hinges are attached to each end, which are then joined by pins. The top of each segment is T-shaped to allow pick up by a special vehicle and lateral movement from 1.2 to 5.5 m [4 to 18 ft]. The T slot is engaged by the vehicle conveyor system and the where:

OHBDC = factored braking force as specified in the 3rd edition of the *Ontario Highway Bridge Design Code*

LFD = factored braking force as specified in the AASHTO Standard Specifications (Load Factor)

LRFD = factored braking force as specified in previous versions of the LRFD Specifications (up to 2001 Interim edition)

LRFD′ = factored braking force as specified in Section 3.6.4

CHBDC = factored braking force as specified in the *Canadian Highway Bridge Design Code*

The sloping portion of the curves represents the braking force that includes a portion of the lane load. This represents the possibility of having multiple lanes of vehicles contributing to the same braking event on a long bridge. Although the probability of such an event is likely to be small, the inclusion of a portion of the lane load gives such an event consideration for bridges with heavy truck traffic and is consistent with other design codes.

Because the LRFD braking force is significantly higher than that required in the Standard Specifications, this issue becomes important in rehabilitation projects designed under previous versions of the design code. In cases where substructures are found to be inadequate to resist the increased longitudinal forces, consideration should be given to design and detailing strategies which distribute the braking force to additional substructure units during a braking event.

3.6.5 Vehicular Collision Force: *CT*

3.6.5.1 Protection of Structures

The provisions of Article 3.6.5.2 need not be considered for structures which are protected by:

- An embankment;
- A structurally independent, crashworthy ground-mounted 54.0-in. high barrier, located within 10.0 ft. from the component being protected; or
- A 42.0-in. high barrier located at more than 10.0 ft. from the component being protected.

In order to qualify for this exemption, such barrier shall be structurally and geometrically capable of surviving the crash test for Test Level 5, as specified in Section 13.

C3.6.5.1

For the purpose of this article, a barrier may be considered structurally independent if it does not transmit loads to the bridge.

Full-scale crash tests have shown that some vehicles have a greater tendency to lean over or partially cross over a 42.0-in. high barrier than a 54.0-in. high barrier. This behavior would allow a significant collision of the vehicle with the component being protected if the component is located within a few ft. of the barrier. If the component is more than about 10.0 ft. behind the barrier, the difference between the two barrier heights is no longer important.

MEMO TO THE FILE

Job R60042 – I40 – Redmond Rd

Documentation for Reduced Shoulder Width at Underpasses

February 8, 2005

On this date Charlie, Dave, myself and Phil McConnell (via phone) had a discussion in which a request was made to reduce the width of the proposed inside shoulder on Hwy 67/167 from the normal 10'-0" to a minimum 9'-3" at the location of underpasses along Hwy. 67/167. This request was initiated because the proposed typical section and the width of the columns to be placed in the median results in a reduction of the inside shoulder as stated above. The reduction of the inside shoulder to 9'-3", would only occur at the existing McCain Turnaround, the proposed Brookswood Flyover and Kiehl Interchange. (It should be noted that an inside shoulder of 9'-9" will result at the existing McCain Blvd Overpass). It was also discussed that the above dimension could only be accomplished if the pier protection were constructed vertically between piers. (The attached drawings were available and conveyed over the phone to Phil.)

To substantiate this request, we provided Phil with the Green Book discussion of lateral hazards at an Underpass (Pg. 765, entire 3rd Paragraph, edition of 2001) which in summary states," It is desirable that the entire roadway cross-section be carried through the structure without change. However limitations may require some reduction in the basic roadway cross section."

Charlie also instructed me to contact Joe Heflin with FHWA to see if he (Joe) had any concerns with safety issues in reference to:

1. The proposed pier protection being designed vertically
2. The proposed concrete barrier wall matching the width of the proposed pier.
3. A vertical wall being placed between the piers.

Joe contacted Mr. Dick Powers (with FHWA in Washington D.C.). Mr. Powers expressed his approval with a vertical fascia to be used in conjunction with piers and pier protection and even continued the conversation by expressing that the proposal would be "desirable". Mr. Powers conveyed to Joe that larger vehicles tend to ride up a sloped fascia and "snag" the pier and a vertical fascia would eliminate this possibility. Mr. Powers even suggested that AHTD might consider designing our pier protection taller (he sighted Louisiana) to help eliminate pier contact if we continue to place a jersey face design in front of bridge piers.

Phil took the subject under advisement with Mr. Walters. On this date, Mr. Walters approved the proposed design which reduces the inside shoulder to 9'-3" only at the existing McCain Turnaround, the proposed Brookswood Flyover and Kiehl Interchange. The proposed concrete barrier wall located in the median will match the width of the proposed pier. A vertical wall will be placed between the piers if applicable (Hammerheads have and will be used on both flyover ramps).

MEMO TO THE FILE

Job R60042 – I40 – Redmond Rd

Documentation for Reduced Shoulder Width at Underpasses

A 75' transition will be used to transition from the normal median barrier to the width matching the median pier.

Later that afternoon Charlie, Dave and I had a discussion with Phil Brand and Leonard Hall (via phone) concerning the overhead structures foundations to be placed in the median. The attachment summarizes that discussion.

The attached memo was sent to bridge design to eliminate any confusion during the design process.

Mike Fugett