4. Roadside Safety Hardware

As stated in Section 1.0, designers should achieve a balance between competing objectives and constraints when determining how the roadside environment will be configured. The choices made to achieve this balance will be influenced by the:

- Functional classification;
- Design speed;
- Operating speed;
- Posted speed;
- Traffic volumes and composition;
- Drainage considerations;
- Pavement design considerations;
- Right-of-way (ROW) constraints (such as property limits, environmental);
- Other ROW user expectations (such as utility companies);
- Access requirements (such as entrances);
- Constructability considerations;
- Maintenance considerations;
- Funding considerations; and
- Other constraints (such as social, political, technological).

When it has been determined that installation of new roadside safety hardware is justified and cost beneficial for inclusion in a provincial highway project, the hardware specified should meet the safety requirements and criteria specified in this manual and have been implemented in MTO's Contract Preparation System or issued specifically for a project by the appropriate functional office within Highway Standards Branch.

New roadside safety hardware installations, including barriers, terminals, transitions, crash cushions, breakaway sign supports, and frangible base luminaire poles, should meet applicable crash test level acceptance criteria referenced in Section 2.4 and as referenced in each of the following sections for each system. This applies to both permanent systems and temporary systems used in work zones.

The barrier and terminal systems listed in this chapter are complete as of the time of issue of this manual. New systems are often accepted for use on provincial highways between publications of the manual and designers are encouraged to keep informed of the most current version of all standards specifications, special provisions, standard drawings and policy memoranda pertaining to roadside hardware.

Systems shall not be modified from the configurations shown in the standards. Highway Design Office shall be contacted for guidance in case site-specific constraints preclude the use of roadside hardware in its standard configuration.

Existing roadside safety hardware installations on provincial highways providing acceptable in service safety performance and system condition should continue to perform as originally intended until the end of their service life.

4.1 Barrier Systems

Although barrier systems are designed and crash tested to reduce the severity of injuries to occupants in errant passenger vehicles during collisions with roadside obstacles within the roadside environment, dependent on the type of impact, significant vehicle damage can occur along with injury to occupants.- Once a barrier system comes into use, the crash is already in progress. The primary purpose of a barrier system is therefore not to prevent a crash, but rather to minimize the severity of the crash.

The severity of the collision with the barrier system should be less than the severity of an impact with a roadside obstacle (e.g. a fixed object or terrain feature) had the barrier not been in place.- A barrier system is a device which provides a physical limitation through which an errant vehicle would not normally pass. Barrier systems are designed and crash tested to contain or redirect an errant design vehicle of a particular size range, at a given speed and angle of impact.

Barrier systems are categorized into two major categories based on configuration, function, and location:

- Roadside Barrier – a single sided longitudinal barrier system intended to redirect errant design vehicles from departing the roadway and encroaching into the roadside environment.
- Median Barrier– a double sided longitudinal barrier system used to redirect errant vehicles from crossing a median.

Roadside barrier systems are designed and crash tested to redirect errant vehicles that impact one side of the barrier system from either direction (e.g. bidirectional). -They are typically used to shield motorists from natural and man-made obstacles located along either side of the travelled way of highways or ramps. This includes the left side of divided highways with wide medians. Under certain conditions on certain facilities, barriers may also be used to separate high speed vehicular traffic from other facilities such as pedestrian sidewalks, active transportation paths, and snowmobile trails.

A median barrier system is designed and crash tested to redirect errant vehicles that impact either side of the barrier system from either direction within a median. Medians are typically used to separate the travelled ways for traffic in opposing directions, or to separate the travelled ways to manage access (e.g. core-collector systems or service roads).

Temporary barrier systems are designed and crash tested for use in construction work zones to provide physical separation between motorists and certain long term work zone operations. They are typically precast temporary concrete barrier systems or temporary steel barrier systems that are installed on paved surfaces that can be picked up and moved during construction for different construction stages.~~,~~

Steel Beam Guiderail may also be used as a barrier system on work zones for stage construction on granular roadway surfaces to provide positive protection between traffic and the work area. When used on work zones, SBGR will usually be required to be relocated for different construction stages. The system is first specified as a new installation for stage one, then relocated for subsequent stages. The designer should specify whether the system will be ultimately removed or, relocated to remain as part of the permanent roadside barrier system at end of project. Relocation of the SBGR system to be part of the permanent barrier system of the project after completing the last construction stage is preferred. However, relocation to a permanent location may not be possible. Steel beam energy attenuating terminals (SBEATs) should be used as terminal systems on work zone installations. The SBGR working width needs to be taken into consideration if the barrier will be installed in proximity to excavation protection systems. Prior to the 60% completion stage of detail design, the designer should send to the Ministry’s Design Standards and Specifications Office the proposed location and quantity of reduced deflection treatments that may be required associated with work zone installations, along with a typical section(s) showing lane widths, shoulder widths, and offset of the obstacle to the reduced deflection treatment.~~or steel beam guide rail systems installed temporarily through granular surfaces during construction that can be removed, salvaged, and reinstalled for different construction stages.~~

4.1.1 Barrier System Types

Barrier systems are further categorized into three system types based on dynamic deflection characteristics and working width requirements:

- Flexible;
- Semi-rigid; and
- Rigid.

Dynamic deflection is the maximum distance that the barrier system is expected to deflect laterally under a specified design impact, measured from the traffic face of the system. Working width is the distance between the traffic face of the system before impact in accordance with a specified crash test and the maximum lateral position of any major part of the system or vehicle after the crash test.

Flexible barrier systems are generally more forgiving than semi-rigid and rigid barrier systems since much of the impact energy is dissipated during deflection of the barrier system. Greater dynamic deflections of flexible barrier systems tend to result in lower impact forces being imposed on the impacting vehicle than with impacts with semi-rigid and rigid barrier systems. In general, flexible barrier systems consist of three or four steel cables mounted on weak steel posts.

Semi-rigid barrier systems are more rigid than flexible barrier systems and more forgiving than rigid barrier systems. In general, these systems consist of steel beams or rails mounted on strong steel posts.

Rigid barrier systems have minimal working widths and either don’t deflect or have minimal deflection. In general, these systems are constructed from concrete and are embedded into the pavement surface.

Semi-rigid and flexible barrier systems should only be used if there is a sufficient working width provided between the traffic face of the system and the obstacle beyond the back of the system to accommodate dynamic deflection under the specified design impact. If the barrier system is placed too close to the obstacle, the impacting vehicle can deflect the barrier system into the obstacle, allowing the vehicle to interact with the obstacle.

4.1.2 Barrier System Performance

The performance of barrier systems is dependent on the design, installation, maintenance, and post-impact repair. Associated grading and appropriate terminals, leaving ends, or anchorage requirements, should be provided for each specific barrier system in order for the barrier system to perform as designed and crash tested.

In order to be effective, a barrier system should be capable of restraining a selected design vehicle under specified impact conditions (design vehicle of a particular size range, at a given speed and angle of impact). A barrier system should prevent the selected design vehicle from the following:

- Penetrating;

- vaulting over (over-riding); or
- wedging under (under-riding) the installation.

Unless otherwise designed, the barrier system should remain substantially intact so that system elements and debris will not pose an undue risk to occupants in the impacting vehicle or other traffic. The barrier system should be designed and installed to reduce the risk of spearing an impacting vehicle. A vehicle-barrier system collision should result in redirection of the impacting vehicle at a low departure angle that will minimize the risk of interacting with other vehicles. Finally, the collision should not result in excessive lateral or longitudinal deceleration of the vehicle's occupants.

Barrier systems, whether they are rigid, semi-rigid or flexible, should be of sufficient length and be properly terminated and anchored. In the case of rigid systems, sufficient length, embedment and mass are necessary to prevent the system from being displaced significantly upon impact.

Since the dynamics of a collision are complex, the most effective means of assessing barrier system performance is through full-scale crash testing. By standardizing such tests, barrier system designers can compare the relative safety performance of alternative systems. As noted in the following subsections, MTO has started to implement installations of new roadside safety hardware on provincial highways that meets the crash test and evaluation criteria contained in the AASHTO Manual for Assessing Safety Hardware (MASH (2009 or 2016)). Where roadside safety hardware that meets MASH is currently not available or been implemented by MTO, new roadside hardware installations should continue to meet National Cooperative Highway Research Program Report 350 - Recommended Procedures for the Safety Performance Evaluation of Highway Features (NCHRP Report 350 (1993)).

It is important to highlight that the performance and mechanisms of vehicle containment of barrier systems is not always intuitive. Crash-test and in-service behaviour of barriers and crash cushions can be unpredictable and surprise even those with decades of experience designing, simulating and testing barriers. Nuances and variations in seemingly insignificant components such as offset block height, or the presence or absence of a washer can result in major changes in barrier performance and can mean the difference between successful containment of a vehicle and a catastrophic failure. For this reason, it is imperative that systems be installed in exactly the configuration prescribed in this manual and all applicable standard specifications and drawings and any proposed changes, no matter how minor, be made only in consultation with the Highway Design Office.

4.1.2.1 Zone of Intrusion

A phenomenon associated with roadside barriers is that of a portion of the vehicle projecting above and behind the working width envelope of the barrier itself during crash testing and real-life collisions. This is referred to as the Zone of Intrusion (ZOI). This phenomenon is especially pronounced with rigid TL-4 and TL-5 barriers as a result of the truck boxes rotating as the vehicle is contained and redirected with relatively little barrier deflection. Figure 4-1 depicts the ZOI for typical Test Levels 3, 4 and 5 rigid barriers.

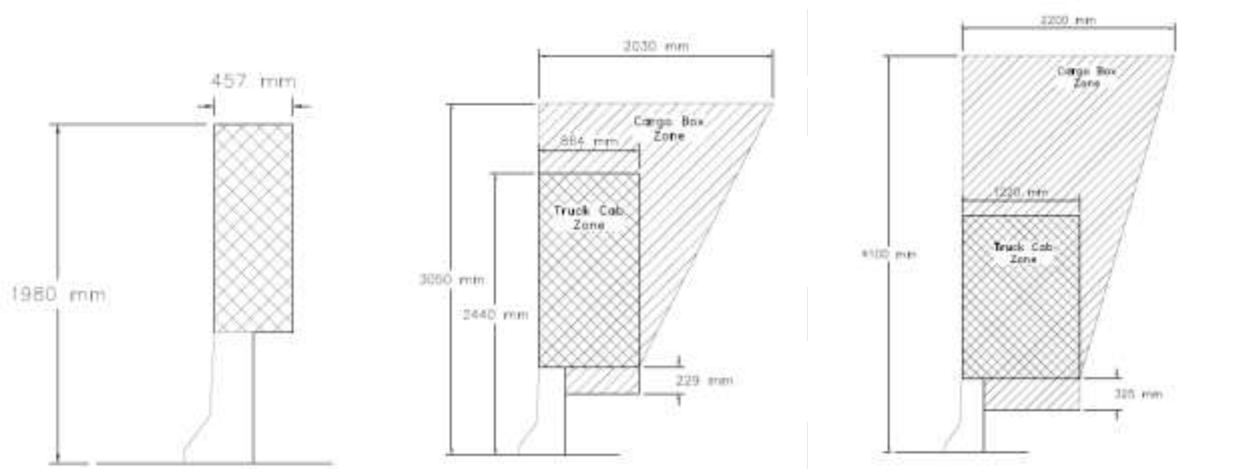


Figure 4-1: Zone of Intrusion for TL-3, TL-4 and TL-5 Rigid Barriers

Highway elements such as bridge piers, overhead sign supports and high-mast poles are often located close to Test Level 5 barriers on narrow freeway medians. For new installations, such objects should desirably be located outside the ZOI. Alternatively, ZOI may be reduced with taller barrier heights. Designers should contact Highway Design Office for guidance and design details for taller barriers to mitigate ZOI.

4.2 Roadside Barrier Systems

A roadside barrier system is a single sided longitudinal barrier system intended to redirect errant design vehicles from departing the roadway and encroaching into the roadside environment.

The following roadside barrier systems have been implemented for installation as new roadside barrier systems on Provincial Highways:

Flexible Roadside Barrier Systems:

- High Tension Three-Cable Guide Rail (HT3CGR, TL-3).

Semi-Rigid Roadside Barrier Systems:

- Midwest Guardrail System, Type M Steel Beam Guide Rail (W-Beam system, TL-3);
- ~~Australian Construction Products Sentry Guide Rail, ACP Sentry (W-Beam System, TL-3)~~Safe Direction, RamShield W-Beam Barrier;
- ~~ACP TL-4 (Thrie Beam system, TL-4)~~
- Ingal Civil Products Ezy-Guard 4 Guide Rail (TL-3);
- Multifunctional Barrier System (TL-3);
- ACP TL-4 (Thrie Beam system, TL-4);
- Ezy-Guard High Containment (Thrie Beam system, TL-4); and
- Guardian 5 Steel Beam ~~Roadside and Median~~ Barrier~~s~~ (TL-5).

Rigid Roadside Barrier Systems:

- Concrete Roadside Barrier (CRB, TL3)~~-~~.

Description and design guidance for each barrier system are described in the applicable sections.

4.2.1 High Tension Three Cable Guide Rail

All MTO contracts advertised after December 31, 2016 that included new or replacement installations of cable guide rail should have specified High Tension Three Cable Guide Rail (HT3CGR) and High Tension Cable Guide Rail Terminal Systems in the contract documents. On MTO contracts advertised prior to December 31, 2016, cable guide rail installations consisted of low tension three cable guide rail systems mounted to wooden posts.

Description:

High Tension Cable Guide Rail (HTCGR) systems are proprietary flexible barrier systems with wire ropes that are pre-tensioned to significantly higher tension values than cables for low tension systems used throughout Ontario since the 1960s. The HTCGR cables are 19 mm diameter, 3 by 7 construction steel wire rope according to AASHTO M 30 with a minimum breaking strength of 173.5 kN, and Type I Class A zinc coating, whereas the low tension system used 12 mm diameter, 7-wire strand steel wire rope according to CAN/CSA G12, grade 800 with a minimum breaking strength of 74 kN and a maximum breaking strength of 100 kN, hot zinc-coated or class A electro-zinc-coated.

At this time, ~~one~~ two proprietary high-tension cable guiderail systems are available.~~,~~ T~~t~~he Safence HT3CGR and Safence HT4CGR systems, both manufactured by Gregory Industries Inc., are~~is~~ currently specified by MTO. The 3 cable system may be used for shoulder and slope installations and slope installations while the 4-cable system may be used only for shoulder installations. ~~This~~ Both systems meet~~s~~ the crash test evaluation acceptance requirements of AASHTO MASH TL-3, with the 4 cable system meeting TL-4.

Figure 4-2~~1~~: Safence HT3CGR Installation

Figure 4-3~~2~~: Safence HT4CGR Installation

Advantages and Disadvantages:

Advantages of HTCGR installations when compared to semi-rigid and rigid barrier systems are:

- Less visual obstruction;
- Suited for open areas where blowing snow may cause drifting;
- Slope installations can provide increased offset from travelled way on narrow embankments to provide additional clearance for snow plows, oversize loads, and likely fewer vehicular impacts;

- System will continue to function after impacts where several posts have been damaged as tension in system should keep cables at proper mounting heights; and
- More forgiving due to lower deceleration forces sustained by vehicle and occupants during impact.

Disadvantages of HTCGR installations when compared to semi-rigid and rigid barrier systems are:

- Higher dynamic deflection and working width requires larger clear area behind the system;
- Cable tension needs to be monitored;
- No transitions currently available for interconnection with other systems;
- More susceptible to damage from snow plows and minor collisions;
- Impacts into terminal may result in entire system becoming non-functional until repaired; and
- More expensive than low tension cable systems historically used in Ontario.

Design Guidance:

HTCGR should be considered when steel beam guiderail cannot provide a minimum offset of 4.25 m from the roadway centerline to the face of SBGR on narrow roadways. HTCGR installations should be offset a minimum of 4.25 m from the roadway centerline to provide clearance for snowplowing operations.

HTCGR systems may be installed on the inside and outside of horizontal curves with centerline radii of 250 m or greater.

The recommended minimum length of a HTCGR system is 100 m including terminals, and the maximum recommended installation length is 6,000 m including terminals.

The Safence High Tension Three Cable Guide Rail (HT3CGR) system may be installed at the edge of shoulder as a shoulder installation, or just beyond the shoulder breakpoint as a slope installation. The Safence High Tension Four Cable Guide Rail (HT4CGR) may only be installed at the edge of a shoulder as a shoulder installation. Shoulder installations have the line posts installed at the edge of shoulder in front of the rounding breakpoint, where the breakpoint in rounding is typically 250 mm from the edge of shoulder as part of the 0.5 m wide rounding. Slope installations have the line posts installed up to 200 mm beyond the shoulder breakpoint on foreslopes as steep as 2H:1V. For new construction, new granular base side slopes should be 3H:1V or flatter as specified.

The Safence HT3CGR system uses three 19 mm diameter pre-stretched cables mounted on proprietary direct driven rectangular galvanized steel line posts spaced at 2 m intervals. The

Safence HT4CGR system uses four 19 mm diameter cables mounted to similar posts spaced at 3 m~~etre~~ intervals. Each cable is tightened to the manufacturer's specified tension typically ranging from 20 kN to 40 kN ~~dependant~~ dependent upon the temperature of the cable. For example, a~~A~~t 20^{0} C, cable tension should be 25.5 kN. At -20^{0} C, cable tension should be 37.3 kN.

Turnbuckles are used to achieve the specified tension in the cables according to Contract Documents and manufacturer's instructions. Turnbuckles should be installed at 305 m intervals for both 3 and 4-cable systems, and may be located above one another (eg. between same posts).

The reported working width for Safence HT3CGR system is 2.2 m based on MASH-09 TL-3 crash test 3-11 for a slope installation on a 2H:1V slope with a installation length of 172.4 m including terminals. The reported maximum dynamic deflection from crash test 3-11 was 2.0 m.

The reported working width for the Safence HT4CGR system is 3.8 m for Test 4-12 for a shoulder installation and 2.8 m for Test 4-11, with 3.0 m post spacing.

Modified Safence HT3CGR line posts may be installed over shallow culverts or other buried obstacles with depths of cover ranging from approximately 1.4 m to 0.8 m. This will require the standard 2256 m long line posts to be shortened by up to 0.3 m or up to 0.5 m to reduce embedment depths while reducing line post spacing from standard 2 m spacing to 1.5 m or 1.0 m spacing accordingly.

Length of need for the HT3CGR system starts at post 6 of the terminal system, or 12 m from the terminal anchor assembly. Length of need for the HT4CGR starts at a point 5 m~~etres~~ from the connection to the anchor block.

HTCGR installations should not be installed in front of or behind curbs.

Retroreflective sheeting measuring 125 mm high for line posts should be wrapped around the approach, traffic, and leaving side of line posts between the top and middle cable at maximum intervals of 20 m on tangents. On horizontal curves, spacing of retroreflective sheeting on line posts should be reduced according to requirements in OTM Book 11.

Approach and leaving ends of Safence HT3CGR system installations should be anchored with Safence end terminals as described below.

Figure 4-4~~2~~: Safence HTCGR~~T~~ installation

End Treatments and Terminals:

One end terminal is required at the end of each run of HTCGR. There is no requirement for intermediate achorages, regardless of the installation length. The 12 m long Safence terminals for shoulder installations are flared away from the edge of shoulder over a length of 20 m (including 5 line posts) to provide an offset of 0.6 m from the edge of shoulder to the centre of the terminal anchor assembly to minimize potential for damage from snowplows and impacts by errant vehicles. In vicinity of the terminal, the roadway is widened beyond the edge of shoulder by at least 1.2 m to accommodate the flaring of the terminal and provide a relatively flat area for impacts by errant vehicles.

The 12 m long Safence terminals for slope installations are not flared away from the edge of shoulder. When line posts and terminal posts are installed 0.2 m beyond the shoulder rounding breakpoint, and assuming the width of rounding in front of the breakpoint is 0.25 m, the offset from edge of shoulder to centre of the terminal anchor assembly is 0.45 m to minimize potential for damage from snowplows and impacts by errant vehicles. In vicinity of the terminal, the roadway is widened beyond the centre of the anchor assembly by 0.6 m or at least 1.05 m to provide a relatively flat area for impacts by errant vehicles.

The area immediately downstream of the terminal anchor assembly for shoulder installations and slope installations measuring 23 m x 6 m should be clear and traversable.

Designers have the flexibility to extend the length of guide rail installations to a location where desirable grading requirements for an end terminal can be better accommodated.

Terminals should be delineated with an Object Marker and Snow Plow Marker placed at the edge of shoulder 2 m in advance of an approach end terminal or 2 m beyond a leaving end terminal to minimize potential for damage from snowplows and impacts by errant vehicles. When terminals are impacted by snowplows or errant vehicles, the terminal system is designed to release the cables during impacts, making the entire length of the HT3CGR installation non-functioning until repaired.

Each cable end of the HT3CGR installation is tethered with check cables to the terminal anchor assembly. The purpose of the check cables is to keep released cable ends in proximity to the terminal anchor assembly when released during an impact with the terminal.

Transitions:

There are currently no acceptable transitions available for transitioning and connecting HTCGR to semi-rigid barriers or rigid barrier systems.

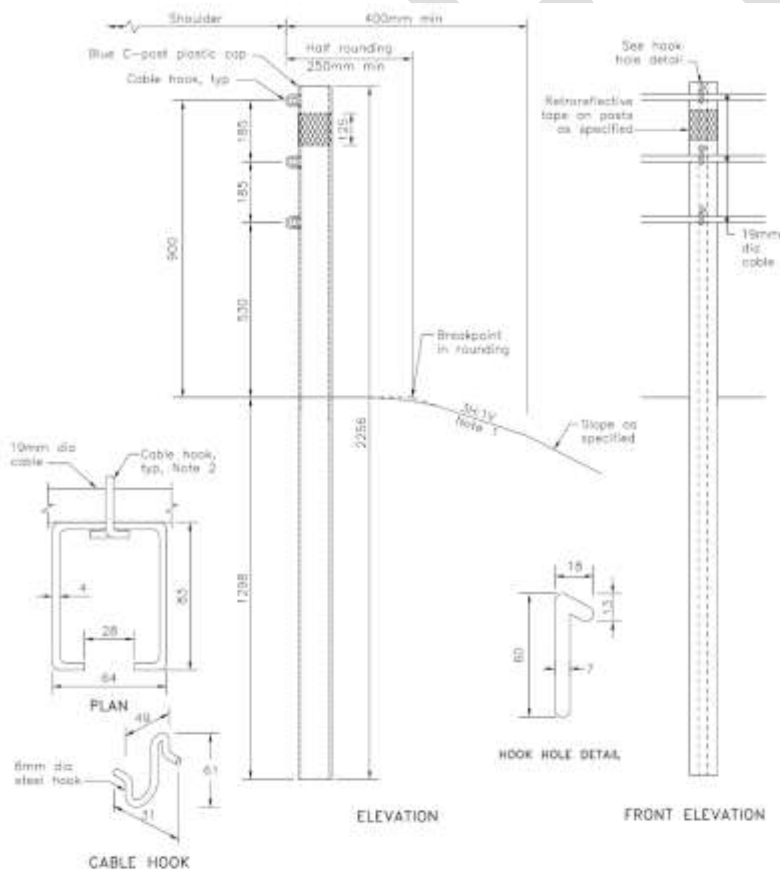


Figure 4-5~~3~~: Safence HT3CGR Shoulder Installation
See applicable standard for Notes.

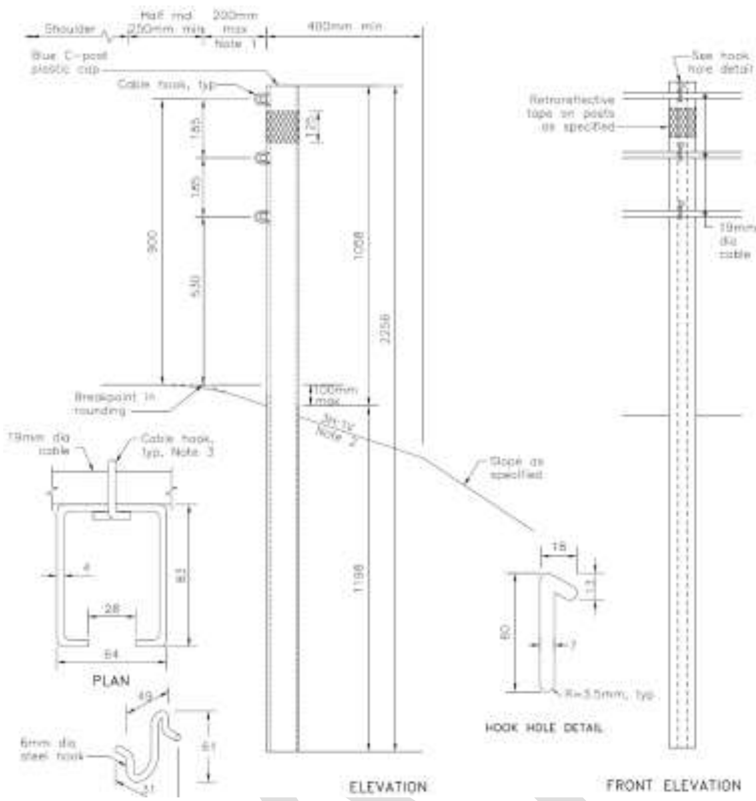


Figure 4-64: Safence HT3CGR Slope Installation

See applicable standard for Notes

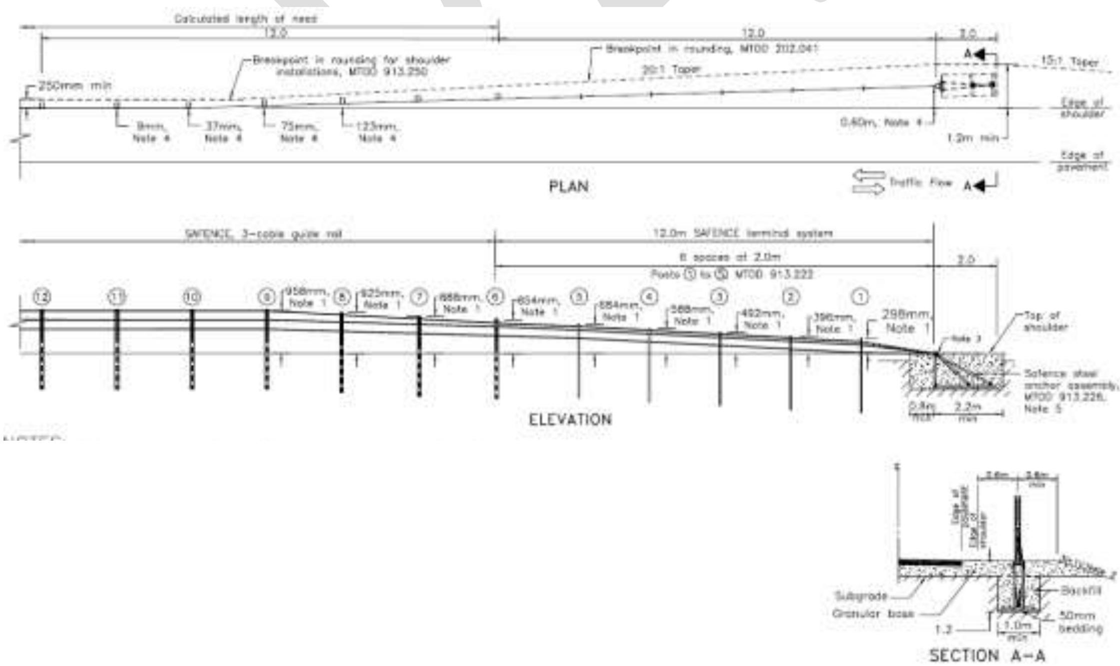


Figure 4-7~~5~~: Safence HTCGRT Shoulder Installation

See applicable standard for Notes

4.2.2 Steel Beam Guide Rail

All MTO contracts advertised after May 27, 2016 that included new installations of Single Rail Steel Beam Guide Rail should have specified Steel Beam Guide Rail in the contract documents. New installations of Single Rail Steel Beam Guide Rail with Channel should be specified at structure connections only.

Each end of an SBGR system should be anchored by an appropriate end treatment, transition to a different barrier type, end terminal system, or structure / concrete barrier connection in accordance with their respective policies in the RDM and applicable standard drawings.

4.2.2.1 Midwest Guardrail System

Description:

Type M SBGR, which is called Midwest Guardrail System (MGS) in the United States, is a non-proprietary single rail SBGR system that was originally developed and crash tested by the Midwest Roadside Safety Facility (MwRSF) at the University of Nebraska through the Midwest States' Regional Pooled Fund Program. The system was developed to improve performance and capacity of legacy SBGR systems previously installed throughout North America over the past sixty years. The revisions to the legacy SBGR system included a modification to the standard W-beam rail to shift the rail splices away from the posts so that they are now located mid-span between posts as detailed in Figure 4-8~~6~~. The top of rail was increased from a nominal height of 685 mm to 785 mm. The system continues to use standard 1829 mm long W150x13 steel posts spaced at 1.905 m and standard 20 cm deep routed wooden or plastic offset blocks (Type M20 SBGR) or 30 cm deep routed wooden or plastic offset blocks (Type M30 SBGR). Type M SBGR, when installed into cross-section of various configurations described below, meets the crash test acceptance requirements of MASH TL-3.

All legacy SBGR and Type M SBGR systems use a W-beam rail with a height of 311 mm and a nominal thickness of 2.67 mm (12 gauge). The W-beam rails have a nominal length of 3.81 m (total rail length of 4.128 m including overlaps for splices) and are overlapped and spliced together using eight splice bolts at each end. W-beam rails are mounted to the offset blocks and posts using appropriate post bolts specific to the type of offset block and post.

The plastic offset blocks offer several installation advantages over wooden offset blocks and are generally preferred by guide rail installers. Plastic blocks are generally lighter than wooden offset blocks and they have a self-hanging finger that allows the block to be hung on the post rather than held in position while the rail is being mounted. Plastic offset blocks include recycled plastics, and they can also be further recycled into plastic products at the end of their service life. Existing pressure treated wooden offset blocks are prone to splitting and cracking as they age, and when removed at the end of their service life are typically disposed of at landfill sites. Currently, three plastic offset blocks are accepted and specified by MTO for new SBGR installations:

- King Block, manufactured by Trinity Highway Products, LLC;
- Mondo Block, manufactured by Mondo Polymer Technologies; and
- P-Block, manufactured by R. G. Steel Corp.

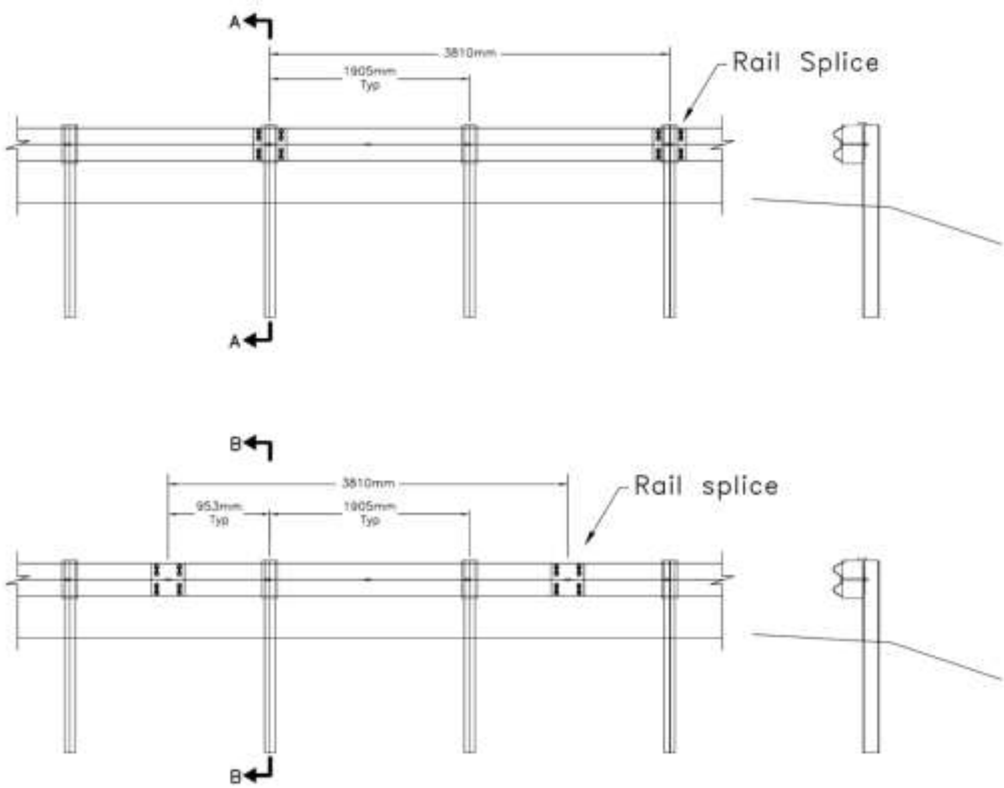


Figure 4-8~~6~~: Rail Splice Locations on Legacy SBGR vs Type M SBGR

At locations where guiderail posts conflict with obstacles, it is acceptable to use wider offset blocks, up to a maximum width of 406 mm on MGS. There is no limit to the number of posts within a run of MGS, however standard-width offset blocks mush be used on all terminals and transitions.

Advantages and Disadvantages:

The main advantages of Type M Steel Beam Guide Rail are:

- Lower maintenance requirements compared to flexible systems;
- Lower dynamic deflection than flexible systems;
- Lower construction cost than rigid systems;
- Can be transitioned and connected directly to structures;
- May be installed at shoulder breakpoints with foreslopes as steep as 2H:1V when installed with longer steel posts; and
- May continue to function after minor impacts prior to repair.

The main disadvantages of Type M Steel Beam Guide Rail are:

- More likely to require to repairs after hits compared to rigid systems;
- Higher dynamic deflection than rigid systems; and
- Higher construction cost than flexible systems.

Design Guidance:

Installations must be offset a minimum of 4.25 m from the roadway centerline, to provide clearance for snowplowing operations. Installations should not be located further than 4.0 m~~etres~~ from the edge of the travelled way.

Type M systems may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater. Sharper radius curves require rails to be shop bent at the manufacturer's plant prior to hot dip galvanizing.

The minimum installation length is 25 m including terminals and leaving end treatments, and there is no maximum installation length.

Standard post spacing is 1.905 m, which may be decreased to 0.952 m ~~or 0.476 m~~ to reduce dynamic deflection during impacts. Alternatively, a continuous hollow structural steel section may be substituted for offset blocks to reduce deflection. See Table 4-~~.~~1.

Standard rail mounting height for Type M SBGR measured at face of barrier to top of rail is 785 mm +/- 25 mm. Type M SBGR can accommodate future pavement overlays up to 50 mm in thickness as long as the top of rail is maintained at a minimum height of 710 mm.

Type M20 SBGR should be installed at the edge of shoulder with 1.0 m rounding, where the breakpoint in rounding to a 3H:1V or flatter granular sideslope is a minimum of 500 mm from the edge of shoulder~~. For additional details see Figure 4-7~~.

Type M30 SBGR may be installed beyond the edge of shoulder when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1.

Type M30 SBGR may be installed a maximum of 125 mm behind barrier curb for TL-3 installations, and a minimum of 1.8 m behind barrier curb with boulevard or sidewalk for TL-2 installations. See Figure 4-9~~7~~.

Type M20 SBGR with longer 2.438 m long W150x13 steel posts may be installed adjacent to shoulders with the traffic face of post set at the breakpoint in rounding to a 2H:1V or flatter granular sideslope. Erosion of the 2H:1V granular sideslope is a concern which may result in increased maintenance costs and reduced performance of the barrier. This configuration should be used when alternatives are limited. At top of the 2.438 m long post, the number “8” is stamped to signify that the post is 8 feet (2.438 m) long, and when damaged, should be replaced with a 2.438 m long post.

Type M SBGR posts may be installed into solid rock by drilling or breaking out a hole in the rock to allow rotation of the steel posts during impacts. For solid rock within 460 mm of the surface, the diameter of the hole needs to be 530 mm or greater for steel posts. The diameter of the hole below a depth of 460 mm needs to be 254 mm or greater, and advanced to a depth at least 50 mm below bottom of specified post. The front of the hole should align with the traffic face of the post and be backfilled with compacted granular base material.

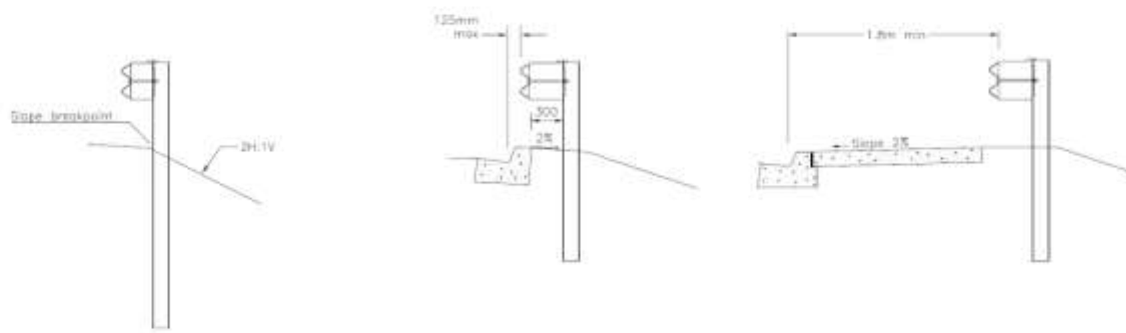


Figure 4-9~~7~~: Various Type M SBGR Installation Configurations

Type M SBGR systems may be installed through asphalt or concrete by providing leave-outs in the surface to allow for rotation of the steel posts during impacts. Steel posts need to be centered in leave-outs that are at least 381 mm long (parallel to roadway). The traffic face of posts need to be placed 50 mm beyond front edge of leave-outs that are at least 381 mm wide (perpendicular to roadway) to provide at least 177 mm of clearance from back of posts to edge of leave-outs. Leave-outs should extend the full depth of asphalt or concrete pavements, be backfilled with compacted granular base material, and be granular sealed.

Long span Type M SBGR may be installed over shallow culverts or buried obstacles with depths of cover less than 1.2 m and lengths (parallel to roadway) up to approximately 7 m. The modification uses three 145 mm x 195 mm drilled breakaway wooden posts with double 145 mm x 195 mm wooden offset blocks installed on either side of a span without posts 7.62 m long. There is also a version with a span without posts 5.715 m long. The embankment over the length of the treatment shall be widened to provide a minimum platform width of 600 mm behind the posts with a slope of 10H:1V or flatter. No obstacles, headwalls or exposed edges of culvert shall be present within 1.6 m of the traffic face of this treatment to allow for deflection during impacts. On both sides of the 7.62 m span without posts, there needs to be at least 19.05 m of SBGR on the approach side and on the leaving side including terminals. For additional details see Figure 4-10~~8~~.

Base plated Type M SBGR may be epoxy bolted to the top of shallow concrete box culverts with lengths greater than 7 m (parallel to roadway) with depths of cover ranging from 1.0 m to 0.207 m. When bolting to the top of precast concrete box culverts, a concrete slab at least 200 mm thick and at least 1.2 m wide (measured perpendicular to roadway) should be specified to accommodate the four epoxy anchors. The 23 mm thick steel base plate is welded to the W150x14 steel post by the manufacturer prior to hot dip galvanizing, and the steel post is cut to length to provide the specified w-beam mounting height.

Alternatively, Type M SBGR may be base plated to a 200 mm thick concrete slab, buried 150 mm below the finished grade using the same method described above. The concrete slab may be continuous along the length of the SBGR or may consist of individual 1,525 mm x 1,525 mm slabs at each post. A minimum of six posts are required to be base plated when using this option.

Transition from Type M SBGR to existing legacy SBGR or existing legacy Steel Beam Energy Attenuators (SBEAT) should take place over a minimum length of 6.6 m.

The cable assembly attaching post 1 of a SBEAT, SBT, or leaving end treatment to the SBGR rail needs to be kept snug to allow tensile forces that develop in the rail during impacts to be transferred to the foundation tube below post 1.

When steel posts are potentially in conflict with a shallow buried utility or drainage pipe, it is acceptable to omit one post in vicinity of conflict. The minimum distance between omitted posts in a SBGR installation is 17.1 m. No modification to the rail is required at the location of an omitted post.

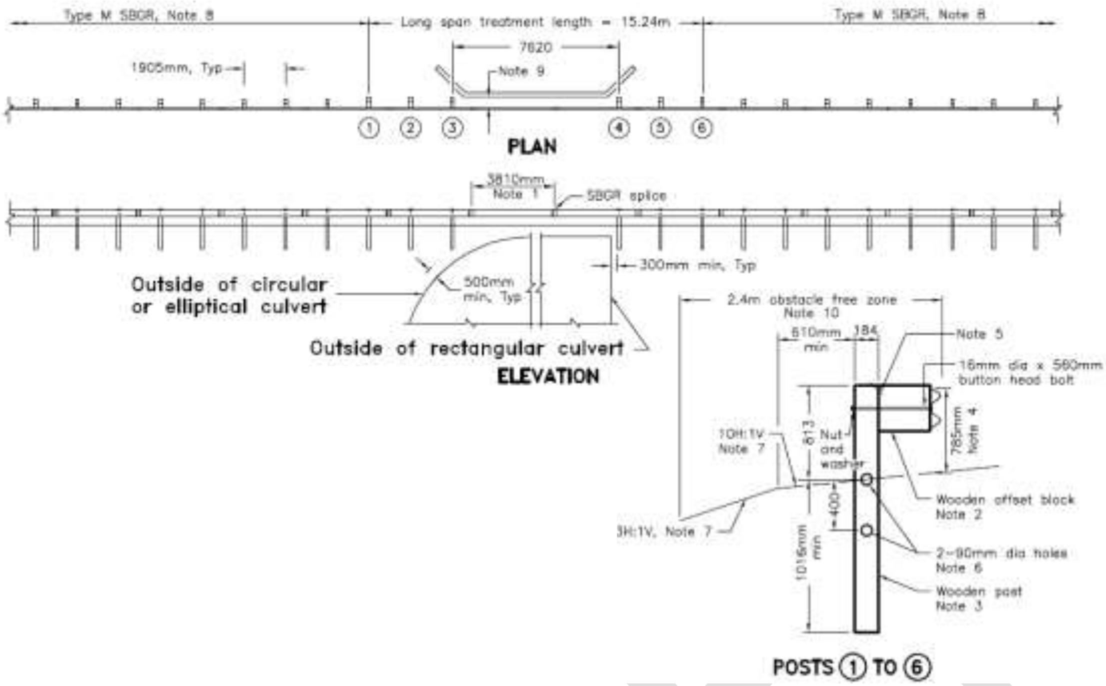


Figure 4-10~~8~~: Long Span Treatment for Low Fill Culverts

See applicable standard for Notes

Working widths for various configurations and test levels are provided in Table 4-1.

Installation Configuration	Post Spacing (m)	Post Length (m)	Working Width MASH-09 (m)	
			TL-3	TL-2
Type M20	1.905	1.829	1.4	1.2
Type M20 adjacent to 2H:1V slope	1.905	2.438	1.4	Note 1
Type M30 adjacent to barrier curb	1.905	1.829	1.3 Note 2	1.0
Type M30 Offset 1.8 m from face of barrier curb	1.905	1.829	Note 3	1.2
Type M20 with ½ post spacing	0.953	1.829	1.0	Note 1
Type M20 with ½ post spacing and HSS tube offset	0.953	1.829	0.8	Note 1
Type M Long Span	7.62	1.829	2.4	Note 1
Type M20 base plated	1.905	Variable	1.3	Note 1

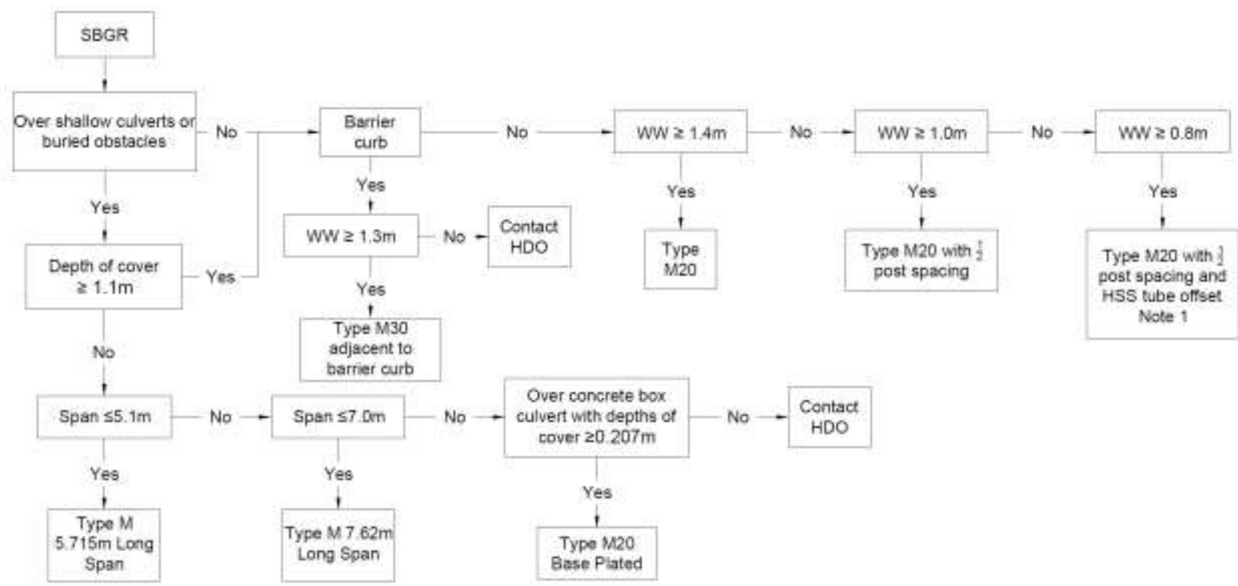
Table 4-1: Working Widths for Type M SBGR Installations

Note 1: Working widths values for this configuration and test level currently not available.

Note 2: Working width based on NCHRP Report 350 crash test 3-11.

Note 3: Configuration not recommended for high-speed roadways with posted speeds of 70 km/h and greater. Configuration meets the crash test acceptance requirements of NCHRP Report 350 TL-2.

The flow chart in Figure 4-11~~X~~ may be used to assist with choosing the correct SBGR treatment to match the field conditions and hazard proximity.



Legend:	Notes:
SBGR: Steel Beam Guide Rail Type M WW: Working Width	1. For a working width between 1.0m and 0.8m, either Type M20 with $\frac{1}{2}$ post spacing or Type M20 with $\frac{1}{2}$ post spacing and HSS tube offset can be used. A. Refer to the appropriate section of the RDM for specific design guidelines for a barrier under consideration, including minimum installation length, requirements for grading and drainage, availability of transitions, terminals and treatments.

Figure 4-11~~X~~: Selection Process for SBGR Treatments

Reflectors with a minimum reflective surface of 100 x 100 mm and flexibility to bend 90 degrees from vertical and self-restore are attached to the top of the Type M steel posts at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Approach and leaving ends of the system installations should be anchored with crashworthy end terminals, leaving end treatments, or transitioned from / to rigid barrier system.

End Treatments and Terminals:

In order to allow development of tensile strength in the SBGR system within the length of need, both ends of the SBGR system installation need to be anchored.

Each end of the SBGR system installation should be anchored by an appropriate end treatment, terminal system, or structure / concrete barrier connection.

A crash worthy terminal system should be installed at the following locations:

- Approach end on divided highways and one-way ramps;
- Approach and leaving end on undivided highways and two-way ramps; and
- Left (median) shoulder on the leaving end on divided highways (eg. divided by a depressed median, median barrier, or median island, and excludes flush medians) when the leaving end is located within the clear zone for opposing traffic.

Crash worthy Steel Beam Energy Attenuator Terminals (SBEAT) currently specified for installations on provincial highway projects are as follows:

- MASH Sequential Kinking Terminal System (MSKT);
- MASH SoftStop Terminal System;
- MASH Max-Tension Terminal System; ~~and~~
- MASH SPIG Gating End Terminal (SGET); and
- Next Generation Terminal (NGT).

Crash worthy Steel Beam Terminals (SBT) currently specified for installations on horizontal curves with centreline radii less than 190 m on provincial highway projects are as follows:

- MASH Slotted Rail Terminal (SRT); and
- MASH Flared Energy Attenuating Terminal (MFLEAT).

SBEATS should be flared away tangentially from the edge of shoulder over their nominal length of approximately 15 m to provide an offset of 0.3 m from the edge of shoulder to the face of rail at post 1 to minimize potential for damage from snowplows and impacts by errant vehicles.

In vicinity of the approach end of an SBEAT, the roadway is desirably widened beyond the edge of shoulder by at least 1.8 m to accommodate the flaring of the terminal and provide a relatively flat area for impacts by errant vehicles.

In vicinity of the leaving end and constrained approach end of SBEAT, the roadway is widened beyond the edge of shoulder by at least 1.2 m to accommodate the flaring of the terminal and provide a relatively flat area for impacts by errant vehicles.

The area immediately downstream of the first post of an SBEAT or SBT installations measuring 23 m x 6 m should be clear and traversable.

Terminals should be delineated with an Object Marker and Snow Plow Marker placed at the edge of shoulder 2 m in advance of an approach end terminal or 2 m beyond a leaving end terminal to minimize potential for damage from snowplows and impacts by errant vehicles. When terminals are impacted by snowplows or errant vehicles, the terminal system is designed to release the cable assembly attaching post 1 of a terminal to the w-beam rail, potentially reducing the ultimate tensile capacity of the SBGR installation until repaired.

The Type M SBGR Leaving End Treatment (LET) was developed to maintain the tension in the SBGR system on the leaving end of installations where impacts from opposing direction vehicles are not likely to occur. The W-beam rail between Post 1 and Post 2 is anchored by a 25 mm diameter cable attachment to a 1.5 m deep post anchor tube at Post 1 as shown in Figure 4-12~~9~~.

The LET is not designed for end-on opposite direction vehicle impacts. The LET should only be installed on divided highways and one-way ramps. The LET should not be installed on undivided highways, as an approach terminal system, or in any location where the LET is located within the clear zone for opposing traffic.

In staged construction it may be necessary to leave partially constructed lengths of guide rail systems exposed to traffic. Research has indicated that guiderails with unanchored ends are capable of redirecting traffic up to approximately 3 panel lengths of the unanchored end, at which point they are unable to contain a vehicle and become gating or behave unpredictably. As such, during construction the final 3 panels of an unanchored end of a steel beam guiderail should never be exposed to potential vehicular impacts. Traffic should also never be exposed to unanchored upstream ends without a crashworthy end treatment installed.

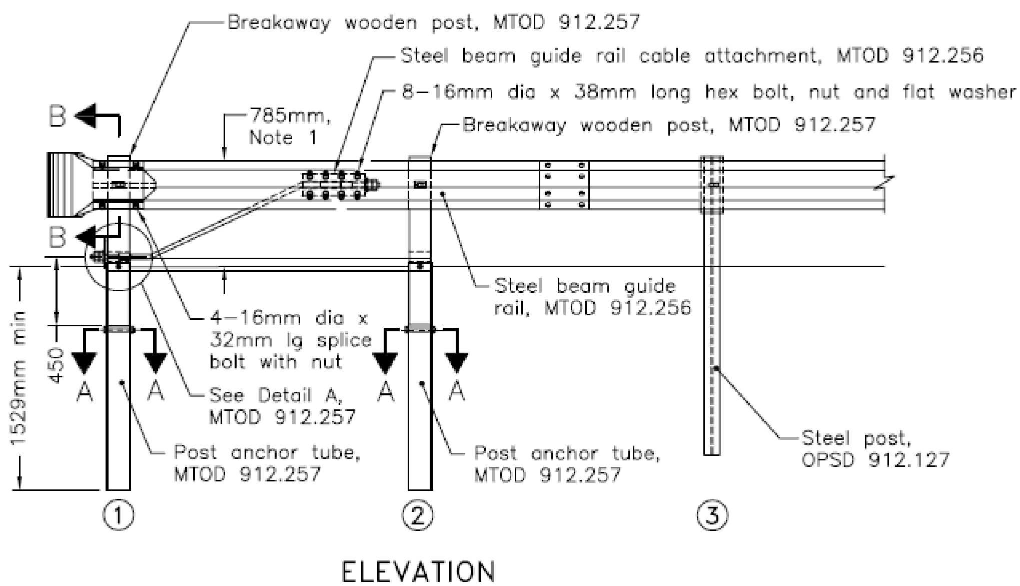


Figure 4-12~~9~~: Type M20 and M30 SBGR Leaving End Treatment

Openings in Steel Beam Guide Rail:

In some cases, it may be desirable to provide a short gap in a run of steel beam guide rail to provide pedestrian access to a property, trail or shoreline. These gaps are often constructed in existing runs of guide rail and typically are terminated with a double “fishtail” end treatment which does not provide adequate anchorage and compromises the functioning of the guiderail for a length of several metres on both sides of the gap.

Where a pedestrian gap is required, a 1 m~~etre~~ gap is available for use. The Pedestrian Access Terminal (PAT) has been crash tested and can be used on ~~a~~ low-speed highways with posted speed 50 km/h or less. It is not recommended for use on high-speed facilities.

Figure 4-13~~0~~: Pedestrian Access Terminal (PAT) for Steel Beam Guide Rail, courtesy of Northern Infrastructure Products (www.northern-ip.com)

Transitions:

SBGR can be connected directly to rigid barrier systems, as well as to structures, including bridge parapet walls. Rigidity transitions are used to reduce the likelihood of vehicle snagging, pocketing or penetration. Only transitions and connection details active in the Contract Preparation System should be used on the provincial highway system. Figure 4-13~~0~~ shows the legacy SBGR with channel system connection to a concrete parapet wall.

Rigidity transitions provide a gradual increase in stiffness from semi-rigid SBGR systems to rigid barrier systems or concrete parapet walls through use of decreased post spacing, thicker w-beam materials, nested w-beams (double thickness), thicker thrie beam sections, steel tubes, or steel plates/channels. Transitions should be of sufficient length to accommodate changes in deflection characteristics between semi-rigid and rigid systems. No gaps or discontinuities are permitted between the approach barrier system and the rigid element.

The connection between a semi-rigid SBGR system and a rigid barrier or concrete wall is accomplished by bolting the W-beam shoe, Thrie Beam shoe, and any steel plates that may be part of the transition treatment, to the concrete cross section using anchors or through bolts with steel plates on the back side. Different details can be used for high-speed installations (TL-3) and low speed installations (TL-2) as shown in Figures 4-14~~1~~, 4-15~~2~~ and 4-16~~3~~.

Standards exist for two thrie beam SBGR to structure connections. Both have been crash tested to MASH TL-3. Both use a standardized concrete parapet end section with curb and gutter approaches, using an embedded steel anchorage with standardized offset to connect the thrie beam end shoe to the parapet. Although the legacy W-beam and channel connection remains available, use of MASH tested structure connections is encouraged whenever possible.

The Long Span Structure Connection (LSSC) shown on Figure 4-~~11~~15~~2~~ is a proprietary connection meets MASH TL-3. It was designed to connect to a vertical face of concrete through nested thrie beams, steel tubes, and a third thrie beam on the field side of the 2.7 m long gap. The advantage of this transition is that it does not require the use of close-spaced posts near the concrete parapet. These posts often conflict with steep slopes and underground installations on bridges.

The thrie beam buttress connection shown on Figure 4-16~~3~~ is a non-proprietary connection that was developed by the Midwest Road Safety Facility and meets MASH TL-3. It consists of a full to half to quarter post spacing transition, with the final 6 posts being of extended length to provide additional rigidity.

~~Other MASH compliant transitions may require the use of nested thrie beams, buttressed end of the concrete parapet wall, steel plates, concrete curbs, and the use of close-spaced posts to provide rigidity transition. Figure 4-12 shows a MASH TL-3 compliant system that consists of nested thrie beams connected to a buttressed concrete shape that can be used both as structure connection and as a concrete barrier to SBGR system.~~

Both approach and leaving end transitions and connections on undivided highways are the same other than beams are lapped in direction of traffic in the adjacent lane.

The leaving ends of structures and rigid barrier systems on divided highways do not normally require transitions unless required to shield other obstacles or high fill embankments. Where protection is necessary downstream of a rigid system, a rigidity transition should be provided ahead of a semi-rigid system.

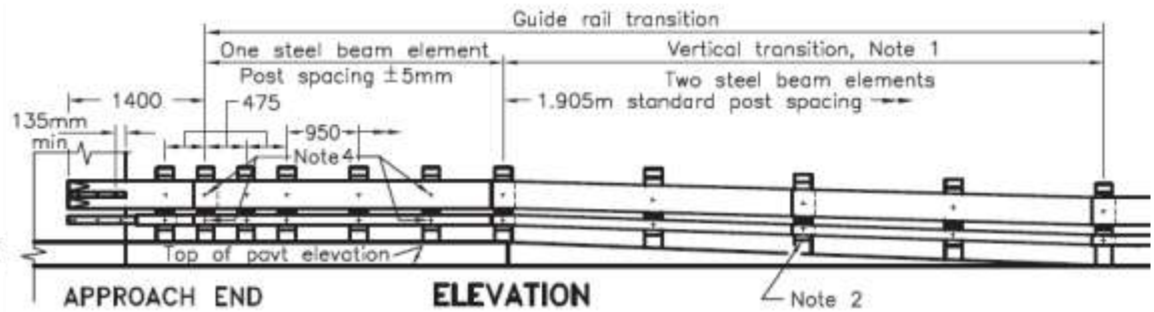


Figure 4-14~~1~~: Legacy SBGR with Channel Connection to Concrete Parapet Wall, See applicable standard drawing for Notes

Figure 4-15~~2~~: MASH TL-3 Long-Span Structure Connection (LSSC)

Figure 4-16~~3~~: MASH TL-3 Thrie Beam Connection to a Buttressed Concrete Wall

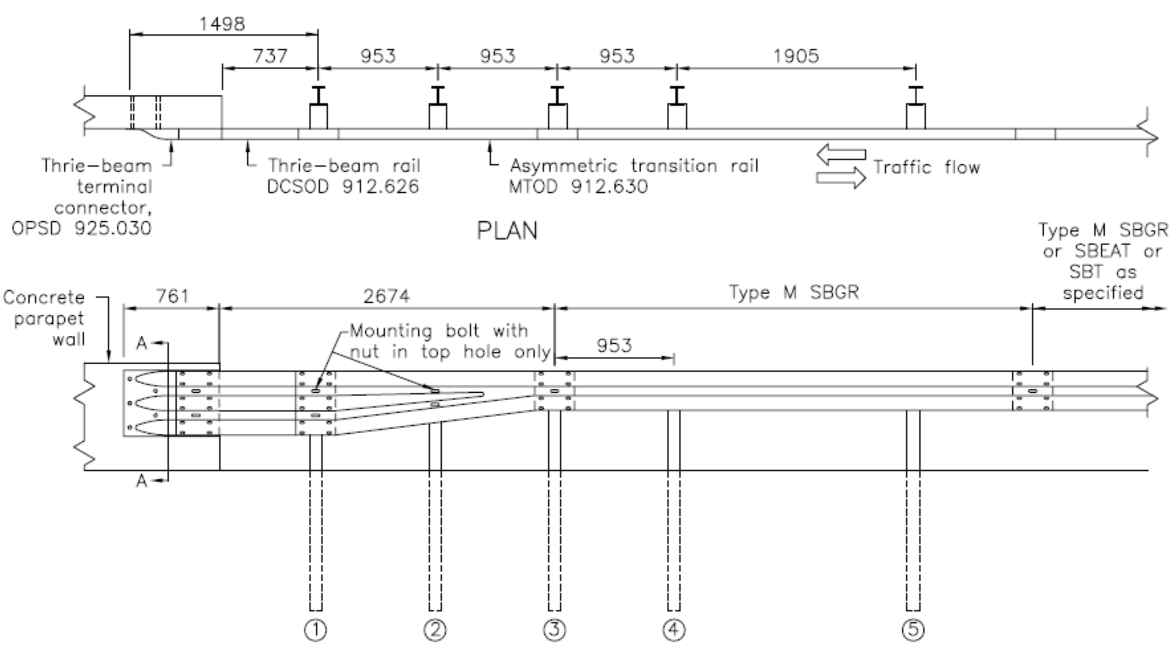


Figure 4-174: MASH TL-2 SBGR Connection to Rigid Barrier on Low Speed Roads

4.2.2.1.1 N-Cap Steel Beam Guide Rail Post Covers

The N-Cap Steel Beam Guide Rail Post Covers is a non-proprietary post cover developed by Gregory Industries Inc. This product is intended for use where there is an identified risk of injury to pedestrians or cyclists who may encounter the exposed top edges of a steel guide rail post. The N-Cap is not intended to improve the safety performance of the guide rail in the event of a motor vehicle crash.

Only Type M guide rail posts are compatible with these standard post covers. The N-Cap is connected to the top, rear of the I-Beam post on the side opposite the guide rail face. Installation requires sliding the cap onto the post and securing it with at least one Guardrail Splice Bolt and guide rail nut through the pre-drilled holes, as shown in Figure 4-18~~XX~~. Post covers shall be installed according to manufacturer's instructions at locations specified in the Contract Documents.

Figure 4-18~~XX~~: N-Cap Steel Beam Guide Rail Post Covers

~~4.2.2.2 Australian Construction Products Sentry Barrier System~~

~~Description:~~

~~Australian Construction Products (ACP) Sentry Barrier is a proprietary single rail SBGR that was developed and crash tested by Australian Construction Products. The system, when installed into cross-section of various configurations described below, meets the crash test acceptance requirements of MASH TL-3.~~

~~ACP Sentry Barrier systems uses the same W-beam rail as Type M with a height of 311 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81m, including the same splicing detail as Type M. Posts are C-shaped steel channels, 72 mm x 115 mm with a specially designed opening to facilitate mounting the rail to the post. Overall system height is 800 mm to the top of the rail with the top of the posts being 10 mm lower than the top of the rail. The system was crash tested with 4 m nominal length rails, posts every 2 m, and rail splices every second post. The system as specified uses 3.81 m nominal length rails (standard rail length), posts every 1.905 m and rail splices located mid-span between posts. This configuration is functionally equivalent to that which was crash tested.~~

~~The system does not make use of offset blocks. The rail is bolted directly to the C-posts using a bolt, nut and proprietary washer.~~

~~The MASH TL-3 working width of Sentry SBGR is 1.59m.~~

~~Advantages and Disadvantages:~~

~~The advantages of ACP Sentry when compared to Type M SBGR are:~~

- ~~Narrower profile due to absence of offset blocks;~~
- ~~2H:1V slope installations can be installed at the breakpoint; and~~
- ~~Advantageous for use on rehabilitation projects as they allow for shoulder width to be preserved when roadway grade is raised~~

~~The disadvantages of ACP Sentry are:~~

- ~~Treatment options such as long span, reduced post spacing, omitted post and short radius are not currently available;~~
- ~~Direct connection to rigid barrier not currently available;~~
- ~~Cannot be installed adjacent to curb and gutter; and~~
- ~~Higher construction cost~~

~~**Design Guidance:**~~

~~Installations must be offset a minimum of 4.25 m from the roadway centerline, to provide clearance for snowplowing operations.~~

~~ACP Sentry systems may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater. Sharper radius curves require rails to be shop bent at the manufacturer's plant prior to hot dip galvanizing.~~

~~The minimum installation length is 30 m including terminals and leaving end treatments, and there is no maximum installation length.~~

~~Standard post spacing is 1.905 m. Standard rail mounting height for ACP Sentry measured at face of barrier to top of rail is 800 mm +/- 25 mm.~~

~~ACP Sentry SBGR may be installed at the edge of shoulder, where the breakpoint in rounding to a 2H:1V or flatter granular sideslope is a minimum of 250 mm from the edge of shoulder. The rear (non-traffic side) face of the posts may be placed at the breakpoint of a slope as steep as 2H:1V when longer posts are used.~~

~~ACP Sentry SBGR may be installed beyond the edge of shoulder when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1.~~

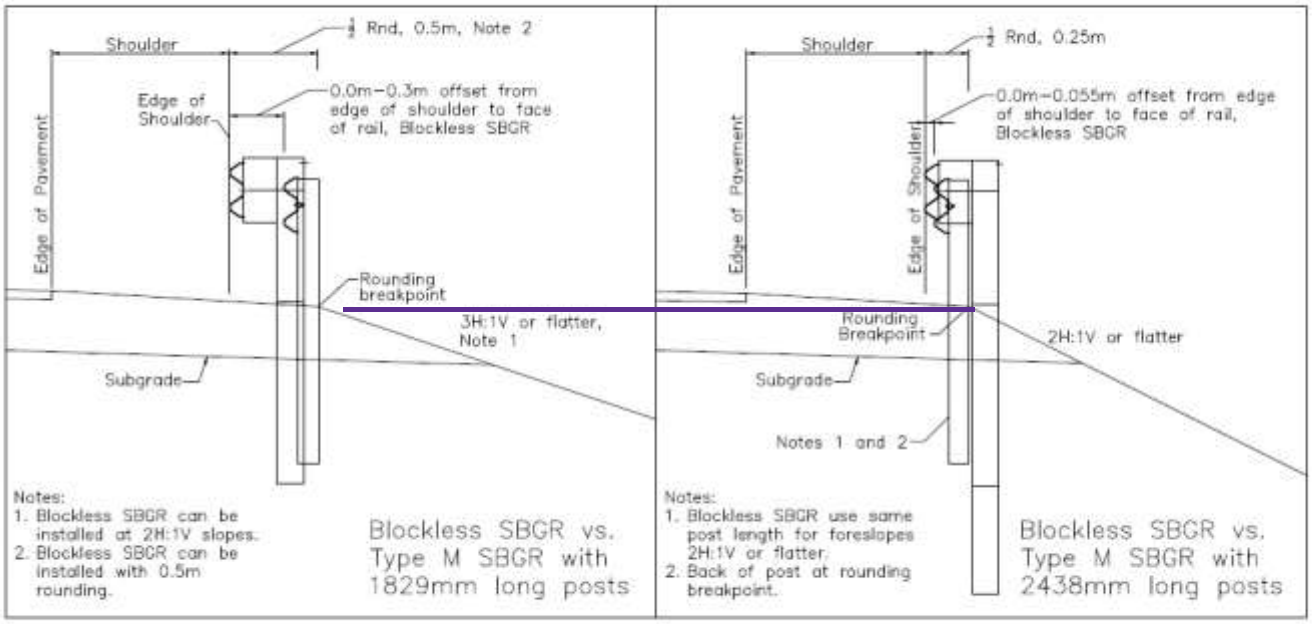
~~ACP Sentry posts may be installed into solid rock by drilling or breaking out a hole in the rock to allow rotation of the steel posts during impacts. Post length may also be shortened depending on the depth of the rock beneath the surface. Installation in asphalt or concrete is not permitted.~~

~~Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the sides of the steel C-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.~~

~~End Treatments and Terminals:~~

~~Approach and leaving ends of the system installations should be anchored with crashworthy end terminals or leaving end treatments as applicable. A transition to rigid barrier system is not available. Transition to a legacy SBGR system with rail splices every second post requires the use of the 2858 mm transition rail detail used to transition the Type M SBGR. Sentry SBGR may also be installed adjacent to Type M SBGR as the two systems have rail splices located mid-span between posts.~~

~~Figure 4-14 illustrates the advantage in placing a proprietary blockless SBGR system adjacent to slopes of 3H:1V and 2H:1V slope compared to SBGR M20.~~



~~Figure 4-15: Blockless SBGR Compared to M20 SBGR at Rounding Breakpoint~~

4.2.2.2 Safe Direction RamShield W-Beam Barrier System

Description:

Safe Direction RamShield W-Beam Barrier is a proprietary single rail SBGR that was developed and crash test by Safe Direction. The system, when installed into cross-section of various configurations described below, meets the crash test acceptance requirements of MASH TL-3.

Figure 4-19~~XX~~: Safe Direction RamShield W-Beam Barrier System

Safe Direction RamShield W-Beam Barrier System uses the same W-beam rail as Type M with a height of 311 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81 m, including the same splicing detail as Type M. Posts are C-shaped steel channels, 70 mm x 100 mm with a specially designed opening to facilitate mounting the rail to the post. Overall system height is 820 mm to the top of the rail with the top of the posts being 50 mm lower than the top of the rail. The system was crash tested with 4 m nominal length rails, posts every 2 m, rail splices every second post and rail heights of between 730 mm and 820 mm above ground level. The system as specified uses 3.81 m nominal length rails (standard rail length), posts every 1.905 m and rail splices located every second post. This configuration is functionally equivalent to that which was crash tested.

The system does not make use of offset blocks. The rail is bolted directly to the C-posts using a bolt, nut and proprietary washer. A release tab in the post allows the rail to detach upon impact, while the post is designed to collapse at the ground surface.

The MASH TL-3 dynamic deflection of the RamShield W-Beam Barrier System is 1.56 m and working width of 1.63 m.

Advantages and Disadvantages:

The advantages of RamShield W-Beam Barrier when compared to Type M SBGR are:

- Narrower profile due to absence of offset blocks; and
- Advantageous for use on rehabilitation projects as they allow for shoulder width to be preserved when roadway grade is raised.

The disadvantages of RamShield W-Beam Barrier are:

- Treatment options such as long span without posts and reduced post spacing are currently not available;
- Direct connection to rigid barrier not currently available;
- Installation adjacent to 2:1 slope currently not available; and
- Higher construction cost.

Design Guidance:

Installations must be offset a minimum of 4.25 m from the roadway centerline, to provide clearance for snowplowing operations.

RamShield W-Beam Barrier systems may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater. Sharper radius curves require rails to be shop bent at the manufacturer's plant prior to hot dip galvanizing.

-The minimum installation length is 30 m including terminals and leaving end treatments, and there is no maximum installation length.

Standard post spacing is 1.905 m. Standard rail mounting height for RamShield W-Beam Barrier measured at face of barrier to top of rail is 800 mm +/- 20 mm.

RamShield W-Beam Barrier may be installed beyond the edge of shoulder when the surface is 10H:1V or flatter and may be installed with a flare rate up to 10:1.

The posts may be installed into solid rock by drilling or breaking out a hole in the rock to allow rotation of the steel posts during impacts. Post length may also be shortened depending on the depth of the rock beneath the surface. Installation in asphalt or concrete is not permitted.

Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the sides of the steel C-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

End Treatments and Terminals:

Approach and leaving ends of the system installations should be anchored with crashworthy end terminals or leaving end treatments as applicable. A transition to rigid barrier system is not available. Transition to a legacy SBGR system with rail splices every second post requires the use of the 2858 mm transition rail detail used to transition the Type M SBGR. RamShield W-Beam Barrier may also be installed adjacent to Type M SBGR as the two systems have rail splices located mid-span between posts.

4.2.2.3 Ingal Civil Products Ezy-Guard 4 Guide Rail

Description:

Ingal Civil Products Ezy-Guard 4 Guide Rail is a proprietary single rail SBGR that was developed and crash tested by Ingal Civil Products. The system, when installed into cross-section of various configurations described below, meets the crash test acceptance requirements of MASH TL-3 and NCHRP Report 350 TL-4.

The as-implemented Ezy-Guard 4 system uses the same W-beam rail as Type M with a height of 311 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81 m, including the same splicing detail as Type M. Posts are Z-shaped hot rolled flat steel, 50 mm x 90 mm with specially designed resistance and positioning tabs to facilitate mounting the rail to the post. Overall system height is 787 mm to the top of the rail with the top of the posts being 10 mm lower than the top of the rail. The system was crash tested with 4 m nominal length rails, posts every 2 m, and rail splices every second post. The system as specified uses 3.81 m nominal length rails with posts every 1.905 m and rail splices located mid-span between posts. This configuration is functionally equivalent to that which was crash tested.

The system does not make use of offset blocks. The rail is attached to the Z-posts using a proprietary Carriage Assembly and bolt.

The MASH TL-3 working width of Ezy-Guard 4 SBGR is 1.65 m. When installed at the breakpoint of a 2H:1V slope, the working width is 1.95 m.

Figure 4-20~~16~~: Ingal Civil Ezy Guard 4 System

Advantages and Disadvantages:

The advantages of Ezy-Guard 4, when compared to Type M SBGR, are:

- Narrower profile due to absence of offset blocks;
- 2H:1V slope installations can be installed at the breakpoint; and
- Advantageous for use on rehabilitation projects as they allow for shoulder width to be preserved when roadway grade is raised.

The disadvantages of Ezy-Guard 4 are:

- Treatment options such as long span, reduced post spacing, omitted post and entrances are not currently available;
- Direct connection to rigid barrier not currently available;
- Cannot be installed adjacent to curb and gutter; and
- Higher construction cost.

Design Guidance:

Installations must be offset a minimum of 4.25 m from the roadway centerline, to provide clearance for snowplowing operations.

Ezy-Guard 4 systems may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater. Sharper radius curves require rails to be shop bent at the manufacturer's plant prior to hot dip galvanizing.

The minimum installation length is 20 m not including terminals and leaving end treatments, and there is no maximum installation length.

Standard post spacing is 1.905 m. Standard rail mounting height for Ezy-Guard 4 measured at face of barrier to top of rail is 787 mm +/- 25 mm.

Ezy-Guard 4 SBGR may be installed at the edge of shoulder, where the breakpoint in rounding to a 2H:1V or flatter granular side slope is a minimum of 250 mm from the edge of shoulder, or with the rear (non-traffic side) face of the posts right at the rounding breakpoint.

Ezy-Guard 4 SBGR may be installed beyond the edge of shoulder when the surface is 10H:1V or flatter and may be installed with a flare rate up to 10:1.

Ezy-Guard 4 steel Z-posts may be installed into solid rock by drilling or breaking out a 110 – 300 mm hole. The specifically engineered steel Z-post dissipates energy by yielding through bending near ground level. Because of this, a cut out for post rotation is not necessary. Post length may also be shortened depending on the depth of the rock beneath the surface.

Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the steel Z-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

End Treatments and Terminals:

Approach and leaving ends of the system installations should be anchored with crashworthy end terminals or leaving end treatments as applicable. A transition to rigid barrier system is not available. Transition to a legacy SBGR system with rail splices every second post requires the use of the 2858 mm transition rail detail used to transition the Type M SBGR. Ezy-Guard 4 SBGR may also be installed adjacent to Type M SBGR as the two systems have rail splices located mid-span between posts.

4.2.2.4 Multifunctional Barrier System

Description:

The multifunctional barrier is a non-proprietary system ~~developed and tested under the NCHRP Project 22-37~~documented in NCHRP Report 1018. The system meets the crash test acceptance requirement of AASHTO MASH TL-3. Unlike longitudinal barriers designed primarily to shield motorists from roadside hazards such as steep slopes or fixed objects, this system is intended to provide positive protection and physical separation between motorized vehicles and vulnerable road users such as pedestrians and bicyclists, on adjacent facilities.

The system consists of steel posts and a multi-tiered rail configuration designed to accommodate both vehicular impact and pedestrian accessibility. The assembly is supported by 1676 mm long W6 x 8.5 steel posts spaced at 1.67 m intervals.

The traffic-facing side of the system incorporates two primary longitudinal components:

- **Traffic Rail:** A 305 mm x 152 mm x 6.4 mm Hollow Structural Section (HSS) steel tube, mounted with the top of the rail at 813 mm above grade.
- **Rub Rail:** A 102 mm x 102 mm x 6.4 mm HSS steel tube mounted with the top of the rail at 330 mm above grade to mitigate vehicle snagging and potential for underride.

The field side of the system includes integrated features to ensure pedestrian accessibility:

- **Handrails:** Two levels of HSS circular tubing, 48 mm in diameter, positioned at heights of 889 mm and 1041 mm.
- **Cane Rail:** A lower rail with its bottom edge located 25 mm above grade to provide a detectable edge for visually impaired users utilizing canes.

The MASH TL-3 working width of the system is 838 mm while the dynamic defection is 406 mm.

Figure 4-21~~XX~~: Traffic Side/Field Side of Multifunctional Barrier System

Advantages and Disadvantages:

The advantages of the multifunctional barrier system compared to standard guide rail systems are:

- Provides positive protection for vulnerable road users;
- Ensures pedestrian accessibility through the integration of a lower cane-detection rail and dual-height handrails;
- Offers less visual obstruction, improving sightlines for both motorists and vulnerable road users; and
- Extremely low dynamic deflection makes it suitable for narrow separation areas.~~;~~

Disadvantages of the system are:

- Higher initial construction and material costs; and
- Requires a specific, crash-tested Thrie beam transition for connection to standard provincial roadside hardware.

Design Guidance:

Installations must be offset to a minimum of 4.25 m from the roadway centerline, to provide clearance for snowplowing operations.

The minimum installation length is 30 m including terminals and leaving end treatments, and there is no maximum installation length.

The barrier may be installed in a variety of contexts, such as where ROW constraints reduce lateral offset between a motor vehicle lane and non-motorized traffic faculties such as sidewalk, bicycle faculties and shared-use paths.

The barrier and transition systems satisfy MASH TL-3 criteria and are, therefore, considered acceptable for use on high-speed facilities. Given that the barrier exhibits a working width of 33 inches. A minimum working width should be provided to ensure the pedestrian rail components do not encroach into the path area during impact.

Transitions:

A MASH TL-3 compliant transition system was also developed to transition the stiffness and geometry of the multifunctional barrier system to a W-beam guardrail to permit its termination with a MASH compliant W-beam guardrail terminal. This transition incorporates nested Thrie beam rail and reduced post spacing.

Note that the transition and its approach guardrail will not provide the same level of protection for vulnerable users behind the barrier as the multifunctional barrier system. Any standard approach guardrail or terminal system beyond the multifunctional barrier and its transition will have considerably more deflection and potentially more debris.

Figure 4-22~~XX~~: Traffic Side/Field Side of Multifunctional Barrier's Transition System

4.2.3 Concrete Roadside Barrier

All MTO contracts advertised after December 31, 2017 that included new installations of Concrete Roadside Barrier installed on the roadside (e.g. not in a median embedded into asphalt on both sides) should have specified Concrete Roadside Barrier in the contract documents.

Description:

Concrete Roadside Barrier (CRB) is a rigid barrier system designed to redirect vehicles through resistance of lateral forces. Generally, rigid barrier systems differ from other barrier systems since they are not designed to yield upon vehicle impact and they do not deflect significantly.

There are various shapes of concrete barriers used throughout North America such as New Jersey shape, F-shape, and constant slope to name a few. In Ontario, the modified New Jersey shape concrete barrier has been used on provincial highways since the early 1990s which has the hinge point between the lower 55^0 sloped portion of the wall and the upper 1H:10V sloped portion of wall set at a height of 250 mm above the pavement, similar to the F-shape concrete barrier. The original New Jersey shape concrete barrier has the hinge point set at a height of 330 mm above the pavement. The New Jersey shape and F-shape concrete barriers also include a bottom vertical section projecting 75 mm above the asphalt pavement whereas the modified New Jersey concrete barrier used in Ontario does not have the bottom vertical face project above the top of pavement.

F-shape and New Jersey shape median concrete barriers with a minimum height of 810 mm (32”) meet the crash test acceptance requirements of MASH TL-3 when embedded into asphalt pavement on both sides of the barrier.

For roadside installations of CRB without being embedded into asphalt pavement on the back side of the barrier, steel reinforcement and additional embedment depths into granular base are required in order to meet the crash test acceptance requirements of MASH TL-3. Details for installation of both cast-in-place design and pre-cast CRB are provided in Figure 4-23~~15~~.

Advantages and Disadvantages:

The advantages of CRB when compared to flexible and semi-rigid systems are:

- Lower routine maintenance requirements;
- Minimal dynamic deflection;
- Can be used to shield embankments with a foreslope ratio as steep as 1.5H:1V;
- Can be directly connected to structures; and
- System continues to function properly after most impacts, without any repair required.

The disadvantages of CRB are:

- Limited flexibility to accommodate future pavement overlays while maintaining current test level performance level;
- Does not permit overland drainage flow;
- Storm sewer system is required in most situations;
- Higher repair costs after severe impacts that exceed the performance crash test level; and
- Higher construction costs.

Design Guidance:

Cast-in place CRB may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater.

Pre-cast CRB may be installed on the inside and outside of horizontal curves with centerline radii of 90 m or greater. For installations on horizontal curves, the squared ends of each precast unit need to be beveled when cast based on the radii of the curve to provide a good connection with the adjacent pre-cast units.

The minimum installation length is 30 m, and there is no maximum installation length.

Offset from edge of travelled lane should not exceed 4.0 m.

Continuous fully paved surfaces need to be provided between the edge of travelled way and traffic face of CRB with cross-fall not exceeding 10%.

Curbs should not be located between the edge of travelled way and traffic face of CRB.

The CRB design requires a 255 mm embedment into the compacted granular base for additional stability and mass to counteract overturning and sliding. On the backside of CRB, the top of compacted granular base should slope downward at 6% for at least 610 mm to the breakpoint to the 1.5H:1V or flatter granular sideslope. The 1.5H:1V configuration was taken to be the worst case installation scenario during crash testing, and a slope of 2H:1V or flatter is recommended to address erosion concerns. Granular sealing should be provided on granular base for a width of at least 1 m beyond back of CRB.

Precast CRB is fabricated in 4 m or 6 m long units. ~~-~~The units are interconnected using a rebar grid that is placed in an open slot that is cast into each end of the CRB unit.

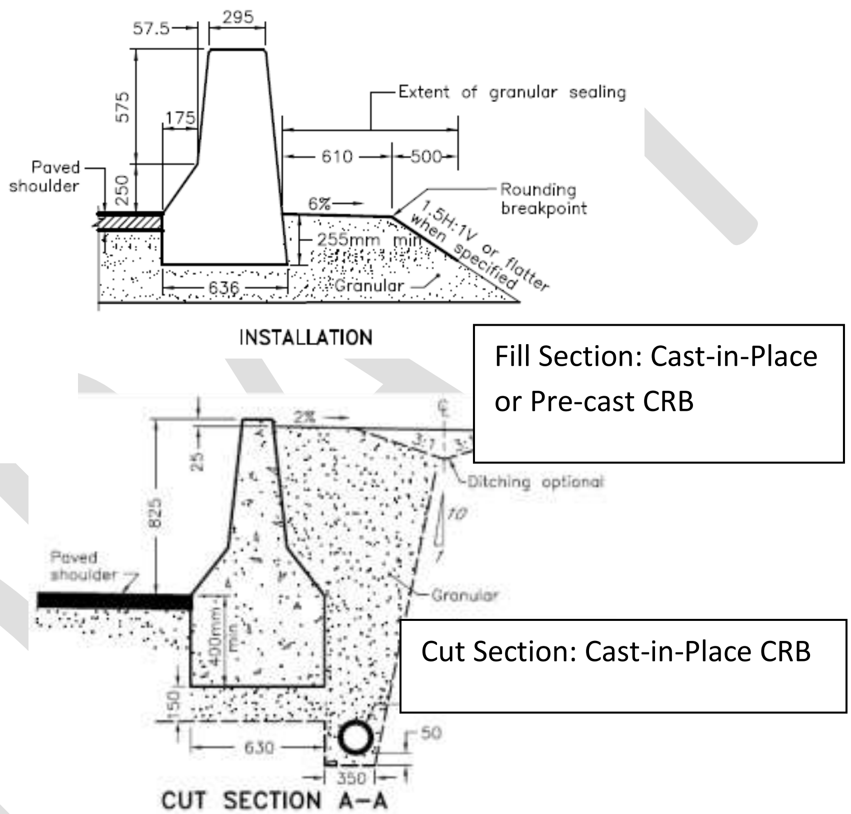


Figure 4-23~~17~~: Concrete Roadside Barrier Installations

Following insertion of the rebar grid into the slot, non-shrink grout is placed in the slot to complete the connection.

CRB should not be used in locations where relief flow from an overland flow route will cross the roadway during flood events.

A minimum offset between the toe of the traffic face of the CRB and the face of an obstacle located behind the CRB should be at least 0.8 m to account for potential shifting of CRB during MASH TL-3 impacts (Dynamic deflection of 142 mm reported for pre-cast design).

Approach and leaving ends of the system installations should be shielded with an appropriate end treatment or transitioned to / from another roadside barrier system.

CRB is cost effective on high volume, high-speed roadways where there is a high frequency of collisions since maintenance and repair of CRB after most impacts is minimal when compared to semi-rigid and flexible systems. CRB may be preferable in locations where the system will be installed close to the traveled way, where site access is limited, and/or where lane closures for repairs would be costly and disruptive.

CRB performs all of the drainage functions of a curb and gutter system, and edge of catch basin grates should be offset 125 mm from toe of CRB.

For cut-installations, only cast-in-place CRB option is currently available as shown in Figure 4-23~~15~~.

End Treatments:

The blunt end or tapered down end of any rigid barrier system is a hazard if it is located where it may be hit by an errant vehicle. Each end of ~~the~~ a CRB system, when not transitioned to another barrier system should shielded with a ~~single sided energy attenuator~~crash cushion at the following locations:

- Approach end on divided highways and one-way ramps;
- Approach and leaving end on undivided highways and two-way ramps; and
- Left (median) shoulder on the leaving end on divided highways when the leaving end is located within the clear zone for opposing traffic.

~~Acceptable single sided attenuators that meet the crash test acceptance requirements of NCHRP Report 350, TL-3 are as follows:~~

- ~~Box Beam Bursting Energy Attenuating Terminal (BB-BEAT)~~
- ~~QuadTrend~~

~~Additional details for each system are provided in Section 4.4.~~

Transitions:

CRB can be connected to semi-rigid barrier systems and other rigid barrier systems including concrete bridge rails.

The standard transition and connection details for CRB connections to semi-rigid barriers are described in Section 4.2.

Standard transitions provide a gradual increase in stiffness from the SBGR system to the CRB. The standard transition should be of sufficient length to accommodate changes in deflection characteristics, shape and height, between the two systems. No gaps or discontinuities are permitted between the approach SBGR and CRB.

4.2.4 Thrie Beam Systems

Thrie beam roadside barriers provide a higher performing alternative to a traditional W-beam system. A thrie beam rail resembles a W-beam rail however it has three ridges and two valleys compared to the two ridges and one valley of a W-beam. A standard thrie beam rail is the same 4,128 mm length as a standard W-beam rail and has a height of 508 mm compared to the 311 mm height of W beam.

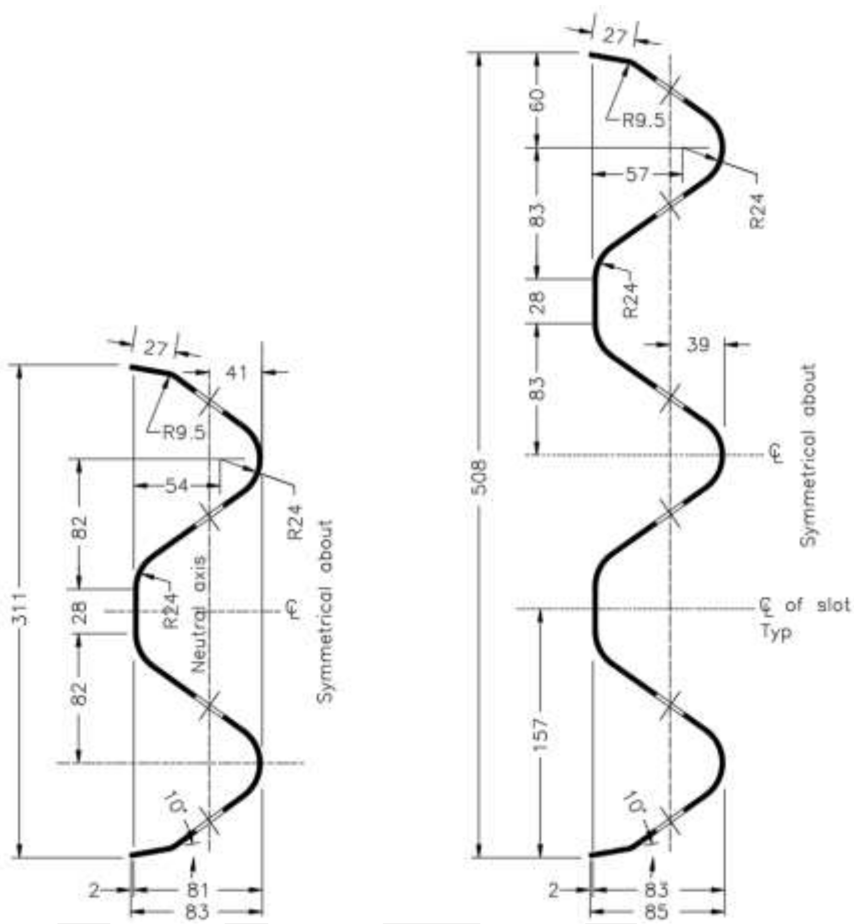


Figure 4-24~~18~~: W-Beam and Thrie Beam Cross Section Comparison

The thrie beam roadside barrier systems implemented for use on provincial highways should be crash tested to MASH Test Level 4 and thus provide superior performance compared to their TL-3-only thrie beam and W beam counterparts. MASH Test Level 4 systems can contain and redirect a 10,000 kg single-unit truck at an impact angle of 15 degrees and a speed of 90 km/h, in addition to meeting the Test Level 3 requirements. They are not intended to redirect tractor-semitrailers as Test Level 5 barriers are capable of, however, they may provide some enhanced capabilities in partially containing such vehicles in less severe impacts. The disadvantage of these systems is the higher installation cost compared to TL-3 SBGR systems. However, this may be partially offset by reduced maintenance costs as these systems are less likely to be significantly damaged in minor impacts with lighter vehicles compared to TL-3 SBGR systems.

Thrie beam roadside barriers are recommended on freeways and high-speed divided highways where barrier is used to shield a water hazard. Thrie beam roadside barriers should also be considered at high-collision locations on roads with commercial traffic volumes in excess of 7,000 vehicles per day.

Approach and leaving ends of thrie beam system installations must be transitioned to a TL-3 W-beam system before being terminated with an appropriate terminal or end treatment. Transitions should be constructed beyond the calculated length of need where TL-4 barrier required to shield an area of concern.

4.2.4.1 Australian Construction Products TL-4 Barrier

Description:

ACP TL-4 barrier is a proprietary single rail thrie beam barrier that was developed and crash tested by Australian Construction Products. The system when installed in a roadside configuration meets the crash test acceptance requirements of MASH TL-3 and TL-4.

ACP TL-4 Barrier uses a standard thrie beam rail with a height of 506 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81 m, with a standard splicing detail. Posts are C-shaped steel channels, 72 mm x 115 mm and 2,000 mm in length with a specially designed opening to facilitate mounting the rail to the post. Overall system height is 1,050 mm to the top of the rail with the top of the posts being 10 mm lower than the top of the rail. The system width is 200 mm. Rail splices are located at every other post. The system has not been crash tested with splices located mid-span between posts.

The system does not make use of offset blocks. The rail is bolted directly to the C-posts using a bolt, nut, and proprietary washer.

ACP TL-4 SBGR should be installed at the edge of shoulder with 1.0 m rounding, where the breakpoint in rounding to a 3H:1V or flatter granular sideslope is a minimum of 500 mm from the edge of shoulder. The minimum distance from the rear face of the post to the rounding breakpoint is 400 mm when TL-3 performance is required and 1,530 mm when TL-4 performance is required.

Figure 4-~~19~~25: ACP TL-4 Barrier

The MASH TL-3 working width of the ACP TL-4 barrier is 1.45 m. The MASH TL-4 working width is 1.53 m.

Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the sides of the steel C-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

4.2.4.2 Ezy Guard High Containment Barrier

Description:

The Ezy Guard High Containment barrier is a proprietary single rail thrie beam barrier that was developed and crash tested by Ingal Civil Products of Australia. The system when installed in a roadside configuration meets the crash test acceptance requirements of MASH TL-3 and TL-4.

The Ezy Guard High Containment barrier uses a standard thrie beam rail with a height of 506 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81 m, with a standard splicing detail. Posts are hot-rolled flat steel Z-shapes with specially designed resistance and positioning tabs to facilitate mounting the rail to the post, 140 mm x 60 mm and 2,000 mm in length. Overall system height is 980 mm to the top of the rail with the top of the posts being 10 mm lower than the top of the rail. The system width is 248 mm. Rail splices are located at every other post. The system has not been crash tested with splices located mid-span between posts.

The system does not make use of offset blocks. The rail is attached to the Z-posts using a proprietary Carriage Assembly and bolt.

Ezy Guard High Containment should be installed at the edge of shoulder with 1.0 m rounding, where the breakpoint in rounding to a 3H:1V or flatter granular sideslope is a minimum of 500 mm from the edge of shoulder. The minimum distance from the rear face of the post to the rounding breakpoint is 1,770 mm.

The MASH TL-3 working width of the Ezy Guard High Containment barrier is 1.16 m. The MASH TL-4 working width is 2.46 m.

Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the sides of the steel Z-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Figure 4-26~~0~~: Ezy Guard High Containment Barrier

4.3 Median Barrier Systems

A median barrier system is designed to redirect vehicles that may impact either side of the barrier system. The primary purpose of a median barrier system is to reduce the potential for and severity of cross-median collisions. Medians are typically used to separate the travelled ways for traffic in opposing directions, or to separate the travelled ways to manage access (e.g. core-collector systems or service roads).

The following median barrier systems have been implemented for installation as new median barrier systems on Provincial Highways:

Flexible Median Barrier Systems:

- High Tension Four-Cable Median Guide Rail (HT4CMGR).

Semi-Rigid Median Barrier Systems:

- Type M Double Rail Steel Beam Guide Rail (Type M SBGR);
- ~~Australian Construction Products Sentry Median Guide Rail~~
- Ingal Civil Products Ezy-Guard 4 Median Guide Rail; and
- Guardian 5 Steel Beam Median Barrier.

Rigid Median Barrier Systems:

- Type M Median Concrete Barrier (Type M MCB); and
- Type TW Median Concrete barrier (Type TW MCB).

Description and design guidance for each barrier system are described in the applicable sections.

4.3.1 High Tension Four Cable Median Guide Rail Systems

Description:

High Tension 4-Cable Median Guide Rail (HT4CMGR) systems are proprietary flexible barrier systems with wire ropes that are pre-tensioned to significantly higher tension values than cables for low tension systems used throughout Ontario since the 1960s. The HTCGR cables are 19 mm diameter, 3 by 7 construction steel wire rope according to AASHTO M 30 with a minimum breaking strength of 173.5 kN, and Type I Class A zinc coating.

HT4CMGR has been installed on Highway 401 between London and Tilbury to mitigate cross-median collisions. Two systems are currently available which have met the crash test acceptance requirements of NCHRP Report 350 and MASH-09 TL-3 and will be further crash tested in accordance with the updated requirements of MASH-16. The systems are the Gregory Safence 4-Cable and Trinity CASS S3 4-Cable.

Advantages and Disadvantages:

Advantages of HT4CMGR installations when compared to semi-rigid and rigid barrier systems are:

- Lower supply and installation costs;
- Less visual obstruction;
- Suited for open areas where blowing snow may cause drifting;
- Can be installed within wide depressed medians ranging in width from 10.5 m (assuming 1.0 m wide median shoulders) to over 23 m with 4H:1V or flatter slopes. Semi-rigid and rigid systems have to be installed adjacent to median shoulders and can't be installed on 4H:1V or 6H:1V median slopes common in Ontario;
- Installations within medians provide increased offset from one or both travelled ways compared to installations immediately adjacent to median shoulders, likely resulting in significantly fewer vehicular impacts;
- System will continue to function after impacts where several posts have been damaged as tension in system should keep cables at proper mounting heights; and
- More forgiving due to lower deceleration forces sustained by vehicle and occupants during impact.

Disadvantages of HTCGR installations when compared to semi-rigid and rigid barrier systems are:

- Higher dynamic deflection and working width requires larger clear area behind the system;
- Cable tension needs to be monitored;

- No transitions currently available for interconnection with other systems;
- More susceptible to damage from minor collisions; and
- Impacts into terminal may result in entire system becoming non-functional until repaired.

Design Guidance:

HT4CMGR installations in medians with 4H:1V slopes should be offset a maximum of 1.2 m from one of the shoulder rounding breakpoints, and a minimum of 2.5 m from the toe of the 4H:1V slope. Based on this configuration with 1.0 m wide median shoulders and 1.0 m wide roundings, minimum median width is 10.32 m. See Figure 4-25~~19~~ for details.

HT4CMGR installations in medians with 6H:1V slopes should be offset a minimum of 2.5 m from the toe of one of the 6H:1V slopes, and no offset requirements from either shoulder rounding breakpoint. Therefore minimum median width would be similar to the 4H:1V median described above, and wider medians would allow placement of the system further away from one of the shoulder rounding breakpoints to further reduce probability of impacts.

HT4CMGR may also be installed in medians with 4H:1V slopes on one side, and 6H:1V slopes on opposite side using guidance from above for determining optimum location of system on either slope.

HT4CMGR may also be installed in medians with 4H:1V or flatter slopes with flat bottom ditches using guidance from above for determining location of system from toe of either slope.

HT4CMGR systems may be installed on the inside and outside of horizontal curves with centerline radii of 400 m or greater. On rural freeways, minimum horizontal curve radii are typically larger than 650 m, with many freeways in Ontario having horizontal curves of 1745 m (1 degree) or flatter.

For installations on horizontal right curves, the HT4CMGR system should be installed on the left side of the median ditch. For installations on horizontal left curves, the HT4CMGR system should be installed on the right side of the median ditch.

The recommended minimum length of a HTCGR system is 100 m including terminals, and the maximum proposed installation length is currently 6,000 m including terminals. Successful installations longer than 6,000 m are reported by several manufacturers.

Each HT4CMGR system uses four 19 mm diameter pre-stretched cables mounted within and/or attached to face of proprietary galvanized steel line posts with various foundation options spaced at intervals ranging from 2 m to 5 m, dependent on desired working width required.

Each cable is tightened to the manufacturer's specified tension typically ranging from 20 kN to 40 kN dependant upon the temperature of the cable. At 20^0 C, cable tension should be 13.7 kN.

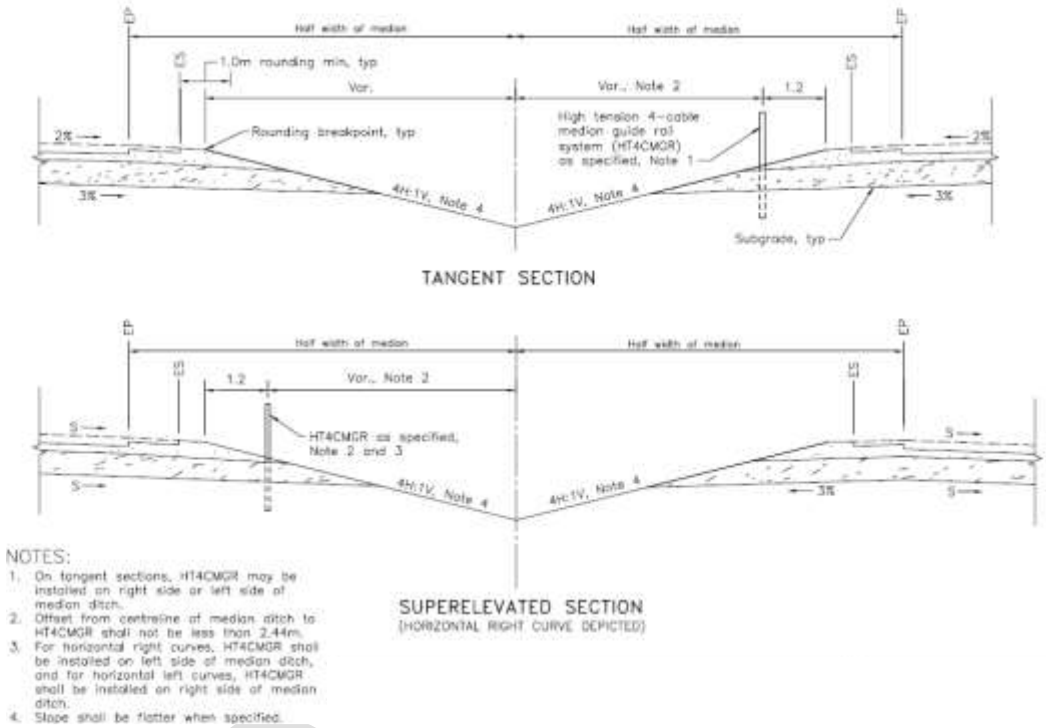


Figure 4-27~~1~~: Typical HT4CMGR installation for rural median with 4H:1V slopes

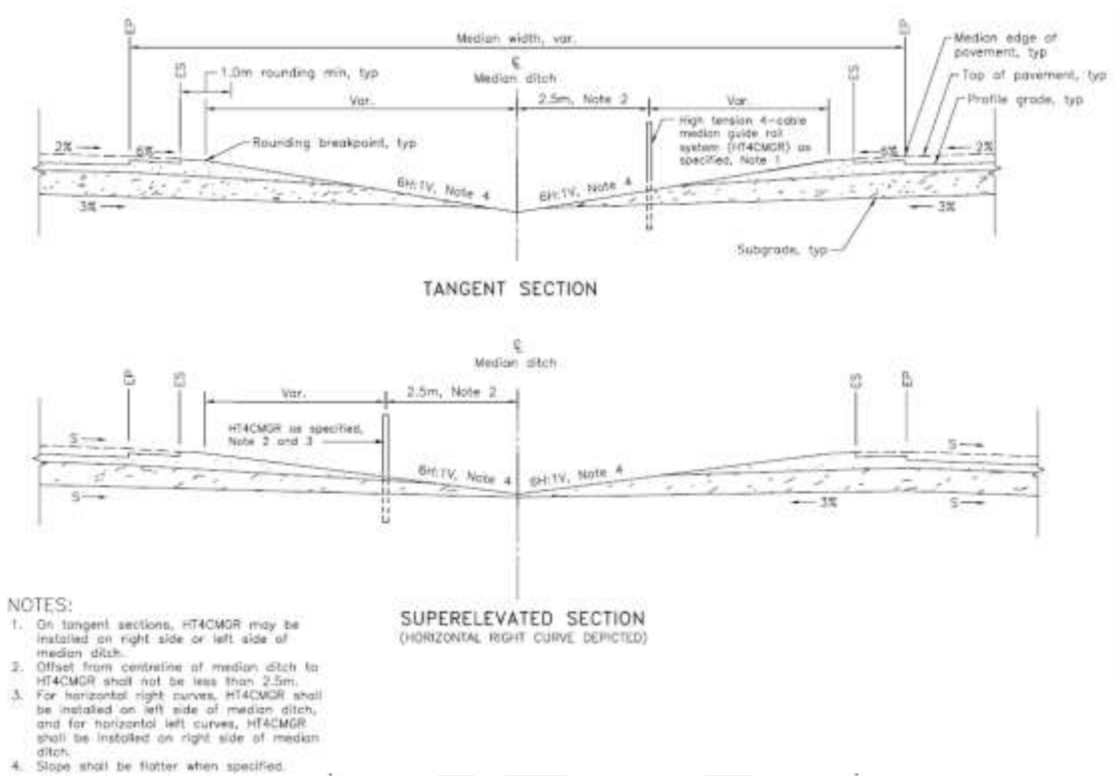


Figure 4-28~~2~~: Typical HT4CMGR installation for rural median with 6H:1V slopes

Turnbuckles are used to achieve the specified tension in the cables according to Contract Documents and manufacturer's instructions. Turnbuckles should be installed at 305 m intervals, and may be located above one another (eg. all four could be located above each other between same posts).

Modified HT4CMGR line posts may be installed over shallow culverts or other buried obstacles dependent on guidance from each manufacturer.

Length of need for the HT4CMGR system is dependent on type of system and terminal.

HT4CMGR installations should not be installed in front of or behind curbs.

When offset 1.22 m or more from the shoulder breakpoint, which is at least 2.72 m from edge of median shoulder assuming 1.0 m wide median shoulders and 1.0 m roundings, reflectors are not recommended. Shoulder rumble strips and post mounted delineators or snowplow markers should continue to be installed along each side of median according to current MTO requirements.

Crashworthy proprietary end terminals should be installed on 6H:1V or flatter slopes as described below.

End Treatments and Terminals:

Crashworthy proprietary end terminals should be installed on 6H:1V or flatter slopes at least 2.44 m from the toe of slope which also intersects the opposite slope that is 4H:1V or flatter. The Gregory Safence 4-Cable barrier is terminated with the Safence Terminal while the Trinity CASS S3 4-Cable system is terminated using the Trinity HARP Terminal. Both systems meet the crash testing requirements of NCHRP Report 350 TL-3.

The area immediately downstream of the terminal anchor assembly measuring 23 m x 6 m should be clear and traversable.

Terminals should be delineated with an Object Marker and Snow Plow Marker placed 0.6 m from edge of closest shoulder breakpoint 2 m in advance of an approach end terminal or 2 m beyond a leaving end terminal to minimize potential for damage from snowplows and impacts by errant vehicles. When terminals are impacted by snowplows or errant vehicles, the terminal system is designed to release the cables during impacts, making the entire length of the HT4CMGR installation non-functioning until repaired.

Transitions:

There are currently no acceptable transitions available for transitioning and connecting HT4CGR to semi-rigid barriers or rigid barrier systems.

Terminating HT4CMGR systems in vicinity of bridges or overpasses will need to overlap with semi-rigid barriers or rigid barrier systems terminated with a crashworthy terminal. Systems cannot be interconnected.

Maintenance Considerations:

HT4CMGR installed over long distances are expected to experience a high volume of impacts, necessitating frequent repairs. Such repairs generally are the responsibility of MTO's maintenance contractors under the requirements of Contractor Directed Maintenance Contracts (CDMC) and may entail a significant volume of change orders where HT4CMGR is installed on highways covered by existing contracts. When planning for new installations of HT4CMGR, designers should consult with Maintenance to determine the anticipated administrative impact of repairs and allow for negotiation of any necessary changes to existing CDMC contracts.

4.3.2 Type M Double Rail Steel Beam Guide Rail

Semi-rigid median barrier systems are generally only installed on freeways within narrow medians less than 10 m wide as an alternative to concrete median barrier when a permeable barrier system is required to not block overland flow routes where relief flow is required across a roadway during flood events.

Type M double rail SBGR when posts are installed behind curb meets the crash test acceptance requirements of NCHRP Report 350 TL-3 and is expected to be crash tested to MASH in the coming years.

Description:

Type M double rail SBGR is similar to Type M SBGR described earlier in section 4.2.2 other than it has two standard W-beam rails mounted to two standard 30 cm deep routed wooden or plastic offset blocks attached to each side of the standard 1829 mm long W150x13 steel posts spaced at 1.905 m intervals. The top of rail height is the same as Type M SBGR with top of rail set at 785 mm +/- 25 mm.

Advantages and Disadvantages:

The main advantages of Type M double rail SBGR are:

- Lower construction cost than rigid systems; and
- Permeable barrier system which should not block overland flow routes where relief flow is required across a roadway during flood events.

The main disadvantages of Type M double rail SBGR are:

- Higher maintenance requirements compared to rigid systems;
- Higher dynamic deflection than rigid systems;
- Will not block potential headlight glare from opposing traffic;
- Steel posts will potentially conflict with buried drainage systems and require curbs to direct surface drainage away from posts longitudinally along median to catch basins;
- Will not accommodate installation of small signs, luminaires, or large sign support legs; and
- Lower performance crash test level than TL-5 tall wall median barrier and 4.3.2.2 Guardian 5 Steel Beam Median Barrier.

Design Guidance:

Much of the design guidance for Type M SBGR provided in section 4.2.2 applies to Type M double rail SBGR.

Type M double rail SBGR may be installed beyond the edge of median shoulders when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1. Steel posts should not be set at bottom of two intersecting 10H:1V slopes which will likely function as a drainage swale.

For narrow medians where adjacent lanes drain towards the median, Type M double rail SBGR should be installed within a raised island with face of curbs offset no greater than 125 mm in front of each w-beam rail. The centre of raised island should not be paved with asphalt or concrete, and should be backfilled with compacted granular base and treated with granular sealant. Figure 4-27~~1~~ shows configuration.

Reflectors with a minimum reflective surface of 100 x 100 mm and flexibility to bend 90 degrees from vertical and self-restore are attached to the top of the Type M steel posts at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Approach and leaving ends of the system installations should be transitioned from/to rigid barrier systems or terminated with a median end terminal or crash cushion.

End Treatments and Terminals:

In order to allow development of tensile strength in the Type M double rail SBGR system, both ends of the system installation need to be transitioned and anchored to a rigid barrier system, or transitioned and anchored to an appropriate double sided crash cushion. Both situations will require a non-standard design to be issued by Highway Design Office.

~~4.3.3 Australian Construction Products Sentry Median Barrier W Beam System~~

~~Description:~~

~~ACP Sentry Median Barrier is a double-sided version of the ACP Sentry barrier that meets the crash test acceptance requirements for MASH TL-3. The barrier consists of the same posts, rails and mounting hardware as the roadside version, with two rails mounted back-to-back to every other post.~~

~~Figure 4-23: ACP Sentry W Beam Median Barrier~~

~~The median system may be installed in a granular or asphalt median and has a working width of 1.49m. When a granular median is used, granular sealing shall be applied as appropriate to mitigate erosion and gravel tracking onto the roadway. The median must be flush, the system may not be installed adjacent to barrier curb.~~

~~Design Guidance:~~

~~ACP Sentry Median SBGR may be installed beyond the edge of median shoulders when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1. Steel posts should not be set at bottom of two intersecting 10H:1V slopes which will likely function as a drainage swale.~~

~~ACP Sentry Median SBGR is not tested in conjunction with concrete curb and gutter and should only be installed in flush medians. Medians may be granular or asphalt with leave-outs cut to allow for post rotation. Exposed granular surfaces should have granular sealing applied to prevent erosion.~~

~~Reflectors with a minimum reflective surface of 100 x 100 mm and flexibility to bend 90 degrees from vertical and self-restore are attached to the top of the C-posts at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.~~

~~Transitions and End Treatments:~~

~~The Sentry Median Barrier may be anchored with either a compatible crash cushion or a Median SBEAT. A transition is required to double-sided conventional guiderail with offset blocks.~~

4.3.4 Ingal Civil Products Ezy Guard 4 Median Barrier W Beam System

Description:

Ingal Civil Products Ezy Guard 4 Median Barrier is a double-sided version of the Ingal Civil Products Ezy Guard 4 barrier that meets the crash test acceptance requirements for MASH TL-3. The barrier consists of the same posts, rails and mounting hardware as the roadside version, with two rails mounted back-to-back to every other post.

Figure 4-294 Ingal Civil Products Ezy Guard 4 W Beam Median Barrier

The median system may be installed in a granular or asphalt median and has a working width of 1.65 m. When a granular median is used, granular sealing shall be applied as appropriate to mitigate erosion and gravel tracking onto the roadway. The median must be flush, the system may not be installed adjacent to barrier curb.

Design Guidance:

Ingal Civil Products Ezy Guard 4 Median SBGR may be installed beyond the edge of median shoulders when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1. Steel posts should not be set at bottom of two intersecting 10H:1V slopes which will likely function as a drainage swale.

Ingal Civil Products Ezy Guard 4 Median SBGR is not tested in conjunction with concrete curb and gutter and should only be installed in flush medians. Medians may be granular or asphalt and do not require leave-out cut to allow for post rotation. Exposed granular surfaces should have granular sealing applied to prevent erosion.

Reflectors with a minimum reflective surface of 100 x 100 mm and flexibility to bend 90 degrees from vertical and self-restore are attached to the top of the steel Z-post at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Transitions and End Treatments:

The Ingal Civil Products Ezy Guard 4 Median Barrier may be anchored with either a compatible crash cushion or a Median SBEAT. A transition is required to double-sided conventional guide rail with offset blocks.

4.3.5 Guardian 5 Steel Beam Median Barrier

The Guardian 5 Steel Beam Median Barrier (G5) system was developed and successfully crash tested in 2016 to meet the crash test acceptance requirements of MASH TL-5.

Description:

ArcelorMittal and Gregory Industries developed their proprietary G5 steel beam median barrier system to meet the requirements of MASH TL-5. The system uses 3 m long high strength steel C posts spaced at 1.52 m intervals (vs 1.905 m for SBGR) with high strength thrie beam and w-beam rails mounted on steel offset blocks on each side. While these beams have the same geometry and appear to be similar to standard thrie beam and w-beam rails, they are 4.572 m long whereas standard rails are 3.810 m long. Having different post spacing and rail lengths from Type M SBGR will ensure that during installation only the longer high strength steel rails will attach to the posts. (eg., standard strength rails cannot mistakenly be used in field).

For the G5 steel beam median barrier system, the top of the w-beam rail is set 1513 mm above the pavement, whereas the top of the thrie beam is set at 894 mm above the pavement.

Dynamic Deflection and Working Width results from the MASH crash tests are summarized in Table 4-2.

Advantages and Disadvantages:

The main advantages of G5 steel beam median barrier are:

- Similar construction cost to tall wall median concrete barrier;
- Higher performance test level than Type M double rail SBGR and HT4CMGR systems;
- Taller system results in reduced zone of intrusion for tractor trailers during TL-5 impacts when compared to tall wall median concrete barrier;
- Permeable barrier system which should not block overland flow routes where relief flow is required across a roadway during flood events;
- Taller height of system may eliminate more headlight glare than tall wall concrete median barrier (1513 mm vs 1050 mm); and

- More forgiving than rigid tall wall median concrete barrier due to lower deceleration forces sustained by vehicle and occupants during impact.

The main disadvantages of G5 steel beam median barrier are:

- Higher maintenance requirements than rigid systems;
- Will not accommodate installation of small signs, luminaires, or large sign support legs; ~~and~~
- Longer steel posts will potentially conflict with buried drainage systems and require curbs to direct surface drainage away from posts longitudinally along median to catch basins; and~~.~~
- Can’t be installed in stepped medians which are common on superelevated horizontal curves.

Design Guidance:

Minimum installation length is 100 m.

MASH Crash Test	Test Vehicle	Impact Speed km/h	Impact Angle Degrees	Dynamic Deflection m	Working Width m
3-10	1100C	101	25.3	0.31	0.31
3-11	2270P	100	25.1	0.49	0.49
5-12	36000V	78.5	15.1	1.32	1.65

Table 4-2: Working Widths for Guardian 5 Steel Beam Median Barrier

System may be installed beyond the edge of median shoulders when the surface is 10H:1V or flatter. Steel posts should not be set at bottom of two intersecting 10H:1V slopes which would likely function as a drainage swale.

For narrow medians where adjacent lanes drain towards the median, system should be installed within a raised island with face of curbs offset no greater than 125 mm in front of each thrie-beam rail. The centre of raised island should not be paved with asphalt or concrete, and should be backfilled with compacted granular base and treated with granular sealant.

Retroreflective tape with a minimum reflective surface of 100 x 100 mm should be attached to the sides of the steel c-post between upper and lower beams at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Approach and leaving ends of the system installations should be transitioned from/to tall wall concrete median barrier, or terminated with a double sided crash cushion.

Specifying a double sided crash cushion will require issuance of a non-standard design for the G5 steel beam median barrier system by Highway Design Office.

Figure 4-30~~25~~: Guardian 5 Steel Beam Median Barrier System
Photo courtesy of Gregory Steel, Inc.

End Treatments and Terminals:

In order to allow development of tensile strength in the G5 steel beam median barrier system, both ends of the system installation need to be transitioned and anchored to a rigid barrier system, or transitioned and anchored to an appropriate double sided crash cushion. Both situations will require non-standard design to be issued by Highway Design Office.

4.3.6 Concrete Median Barrier

Concrete Median Barriers (CMB) are rigid barrier systems designed to redirect vehicles through resistance of lateral forces. Generally, rigid barrier systems differ from other barrier systems since they are not designed to yield upon vehicle impact and they do not deflect.

Concrete median barriers are the most commonly used type of median barrier in Ontario. The prevalence of CMB is due mainly to its low life-cycle cost, effective performance, and low maintenance characteristics, which make it suitable for high speed high volume highways with narrow medians. For opposing directions of travel on freeways and high-speed divided highways with narrow medians, tall wall concrete median barrier should be used which meets MASH TL-5.

CMBs are typically classified by their shape and overall height above top of pavement.

Description:

The modified New Jersey shape concrete barrier has been used for all new installations of concrete median barrier since the early 1990s on the provincial highway system. For additional information about modified New Jersey shape concrete barriers, refer to Section 4.2.3.

Standard heights of CMB used on the provincial highway system are 825 mm and 1050 mm, which is measured from top of adjacent pavement to the top of barrier. These heights do not include the embedded part of the CMB below the top of pavement.

Slip-formed or cast-in-place 825 mm high Type M CMB and Type C CMB, and 1050 mm high Type TW CMB, also known as Ontario Tall Wall, specified on MTO contracts advertised after December 31, 2017 will meet the crash test acceptance requirements of MASH TL-3 and TL-5 respectively.

All three CMB configurations referenced above may be constructed in an asymmetric configuration to accommodate grade differentials typically found between opposing lanes on superelevated curves. The maximum grade differential that can be accommodated is 600 mm.

4.3.6.1 Type TW Concrete Median Barrier

Advantages and Disadvantages:

The advantages of Type TW CMB are:

- Lower maintenance requirements compared to flexible and semi-rigid systems;
- Higher profile addresses headlight glare;
- No dynamic deflection;
- Can be directly connected to structures with concrete TL-5 bridge rails; and
- System can function properly after moderate impacts.

The disadvantages of Type TW CMB compared to semi-rigid and flexible barrier systems are:

- Less forgiving due to higher deceleration forces sustained by vehicle and occupants during impacts;
- Closed drainage system required below barrier to accommodate drainage from median shoulders and lanes draining towards median;
- Will block overland flow in flood prone areas;
- May limit stopping sight distance on inside of horizontal curves with narrow median shoulders, especially when asymmetric CMB required;
- Construction cost is higher relative to semi-rigid median barrier systems; and
- After severe impacts by trucks, expensive repairs may be required to restore CMB.

Design Guidance:

Type TW CMB is the desired median barrier system for installation on freeways and high-speed divided highways with narrow medians less than 10 m wide, except where overland flow needs to be accommodated.

Type TW CMB may also be installed on freeways with narrow medians between core/collector systems, or between freeways and service roads.

The minimum installation length is 30 m, and there is no maximum installation length.

The traversable area between the travelled way and the barrier should be free of obstacles and irregularities, and be sloped no steeper than 10H:1V. This area should be paved, with a minimum depth of 75 mm over a width of at least 3.0 m on both sides of the TW CMB.

Approach and leaving ends of the system installations should be shielded with an appropriate end treatment or transitioned to / from another roadside barrier system.

Type TW CMB should not be installed more than 4.6 m from the edge of the travelled way. An exception is on the inside of horizontal curves, where it is necessary to maintain minimum stopping sight distance. Installation at greater offsets is generally not desirable as the cost of shoulder paving and maintenance becomes excessive.

Curbs should not be installed in front of CMB.

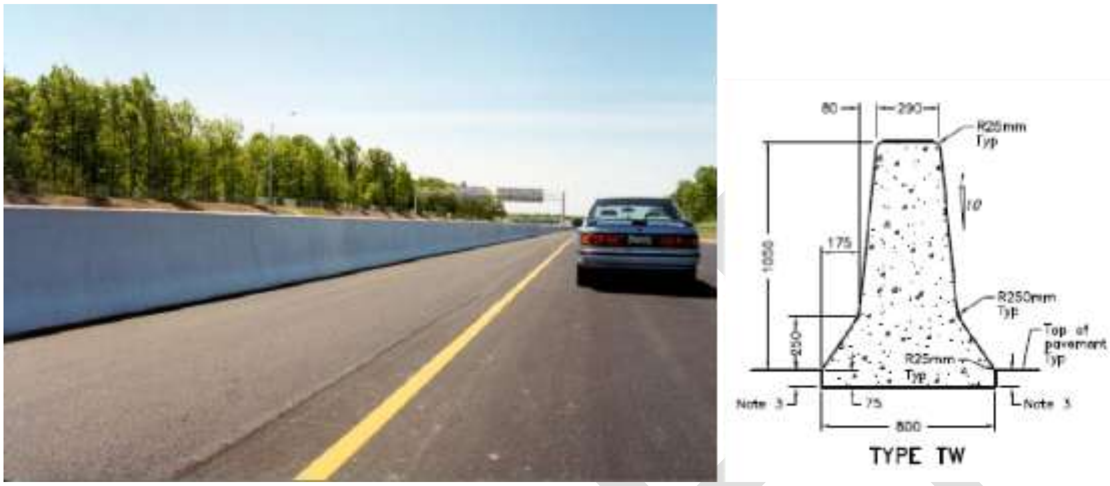


Figure 4-31~~26~~: Tall Wall Concrete Median Barrier installation

End Treatments:

The blunt end of any rigid barrier system is a hazard if it is located where it may be hit by an errant vehicle. Each end of Type TW CMB system should be transitioned to a narrower CMB or treatment and terminated with an appropriate crash cushion.

Transitions:

Both approach and leaving end connections should conform to standard transition design requirements.

Standard designs are being finalized in 2018 for transitioning TW CMB to Guardian G5 Steel Beam Median Barrier system. Standard designs are currently available for connecting TW to TL-5 concrete bridge rails.

4.3.6.2 Type M and C Concrete Median Barrier

The 825 mm high Type M and C CMB are non-reinforced concrete median barrier systems. Type M and C CMBs are typically used as a separator barrier between two adjacent roadways with traffic flows in the same direction, such as core/collector systems.

Advantages and Disadvantages:

The advantages of Type M and C CMB compared to semi-rigid and flexible barrier systems are:

- Lower routine maintenance requirements when compared to semi-rigid systems;
- No dynamic deflection;
- Can be used on horizontal curves;
- Can be connected to structures; and
- System continues to function properly after most minor impacts, without any repair required.

The disadvantages of Type M and C compared to semi-rigid and flexible barrier systems are:

- Does not permit overland drainage flow;
- Storm sewer system is required in most situations; and
- Construction cost is higher relative to semi-rigid systems.

Design Guidance:

There is no maximum installation length.- The minimum installation length is 30 m.

The traversable area between the travelled way and the barrier should be free of obstacles and irregularities, and be sloped no steeper than 10H:1V. -This area should be paved.

Approach and leaving ends of the system installations should be shielded with an appropriate end treatment or transitioned to / from another roadside barrier system.

Type M and C CMB is effective on high volume, high-speed roadways where there is a high frequency of collisions since routine maintenance is typically less for a rigid barrier system when compared to semi-rigid systems. Therefore, Type M and C is desirable in locations where the system will be installed close to the traveled way, where site access is limited, and/or where lane closures are costly and disruptive.

Paving of the adjacent shoulder is required to embed the CMB to prevent deflection of system when impacted.

Type M and C CMB should not be installed more than 4.6 m from the edge of the travelled way. An exception is on the inside of horizontal curves, where it may be necessary to maintain stopping sight distance. Installation at greater offsets is generally not desirable as the cost of shoulder paving becomes excessive.

Type M and C CMB performs all of the drainage functions of a curb and gutter system. Curb and gutter should not be located between the edge of travelled way and traffic face of CMB.

End Treatments:

The blunt end of any rigid barrier system is a hazard if it is located where it may be hit by and errant vehicle.- Each end of Type M and C CMB systems, where it is not transitioned to another barrier system should be treated appropriately with a crash cushion.

Transitions:

Type M and C CMB can be connected to semi-rigid barrier systems including Type M SBGR. The standard transition and connection details reduce the likelihood of vehicle snagging, pocketing or penetration. Only standard transition and connection details should be used on the provincial highway system.

Both approach and leaving end connections should conform to standard transition design requirements.

Standard designs have been developed to transition from Type M and C CMB to concrete bridge rails.