4.4 Barrier End Terminals and Crash Cushions

All MTO contracts advertised after September 1, 2016 that included installations of new Steel Beam Energy Attenuating Terminals should have specified terminals that met the crash test acceptance requirements of MASH TL-3.

All MTO contracts advertised after December 31, 2016 that included installations of new Type M SBGR with approach end terminals located on horizontal curves with centerline radii less than 190 m should have specified Steel Beam Terminals that met the crash test acceptance requirements of MASH TL-3.

All MTO contracts advertised after December 31, 2016 should no longer have specified new installations of Eccentric Loader Terminals (ELT) or Crash-Cushion Attenuating Terminals (C-CAT).

All MTO contracts advertised after May 25, 2009 that included the tender items for permanent and temporary energy attenuators (crash cushions) for installation at ends of permanent or temporary concrete barrier, should have specified energy attenuators that met the crash test acceptance requirements of MASH TL-2 or TL-3, dependent on the posted speed of the facility. NCHRP Report 350 systems may be used in categories where MASH systems are not available.

Errant vehicle impacts with the untreated ends of semi-rigid or rigid barrier systems or fixed objects have a high potential risk of serious injury to vehicle occupants. This is due to high deceleration forces or vehicle instability that would result. Barrier end terminals and crash cushions are used to reduce the severity of such impacts by attenuating collision energy through gradual vehicle deceleration or through vehicle redirection away from the fixed object.

Barrier end terminals and crash cushions primarily serve to lessen the severity outcome of collisions, rather than prevent them from occurring.

An end terminal is normally used at the end of a barrier system where traffic passes on one side of the barrier and protection from a head-on impact is necessary in one direction only. A crash cushion is normally used to shield the end of a median barrier system, a fixed object located in the median, or an object located within a gore area.

A crash cushion may also be used to shield an object on either side of a roadway, if it is more suitable and/or cost-effective than a barrier system.

Crash cushions are also used in work zones to shield the ends of temporary barrier systems.

End terminals and crash cushions are generally designed to safely stop and/or redirect passenger cars and light-duty trucks. For design impacts, these systems are designed to keep deceleration forces below specified limits, resulting in a lower risk of serious injury to vehicle occupants during impacts the system was designed for.

End terminals and crash cushions do not function in isolation. They are selected and designed as one element of an integrated roadside system that includes consideration of the roadway, shoulder, foreslopes, drainage facilities and the roadside environment. These elements should be designed to function in conjunction with one another to maximize safety benefits.

Design Guidance:

Grading between the travelled way and end terminals or crash cushions should be relatively flat (10H:1V or flatter). -The terrain should be free of obstacles that may affect vehicle stability prior to the moment of contact with the end terminal or crash cushion.- When the use of curb and gutter adjacent to end terminals or crash cushions is unavoidable, mountable curb should be used to maintain vehicle stability prior to impact.

The performance of end terminals and crash cushions is dependent on correct installation, maintenance, and post-crash repair. Careful attention should be paid during the design stage to system selection and specification, integration with other design elements, as well as orientation and positioning.- Grading and anchorage requirements, length of need, and suitability to expected traffic characteristics should also receive proper attention.

All end terminals and crash cushions specified on provincial highway project are proprietary products. These products are available exclusively from the manufacturer or designated distributor for the area. Such products are generally purchased as a complete system, with ongoing logistical support (e.g. installer and repair training, technical assistance and replacement components) available from manufacturer or distributor.

4.4.1 SBGR End Terminals

The following steel beam guide rail end terminals are accepted and specified for use on the provincial highway system:

Steel Beam Energy Attenuating Terminal System (SBEAT):

- MASH MAX-Tension Terminal System;
- MASH Sequential Kinking Terminal System;
- MASH SoftStop Terminal System;
- MASH SPIG Gating End Terminal System; and
- MASH Next Generation Terminal System.

Steel Beam Energy Attenuating Terminal System (SBEAT), Median:

- MASH MAX-Tension Median Terminal System.

Steel Beam Terminal (SBT)

- MASH Slotted Rail Terminal System; and
- MASH Flared Energy Attenuating Terminal System.
-

Crashworthy roadside devices should be installed, maintained, and inspected to ensure their condition reflects the as-tested configuration and adheres to manufacturer's requirements. Failure to comply with the nature in which these systems were tested can result in failure which could lead to serious injury or fatality of vehicle occupants.

Installation, maintenance and inspection of guide rail, end terminals, crash cushions, high tension cable guide rail, and small / intermediate sign support systems should be performed by persons with manufacturer-accredited training in these activities.

4.4.1.1 End Terminal Grading

All of the SBGR end terminals specified by the ministry are classified as "gating" systems, a term which describes their behavior when impacted at an angle near the impact head. A gating end terminal allows a vehicle impacting the nose or side of the system immediately downstream of the nose, to pass through the device. For impacts within the length of need, gating end terminals have redirectional characteristics that are compatible with the roadside barrier. Due to the gating performance of these systems, the area behind and beyond all end terminals

should be traversable and free of fixed obstacles. This configuration is illustrated in Figure 4-32.~~25~~

Roadside grading should be designed to accommodate the operation of end terminals and crash cushions. Steel Beam Energy Attenuating Terminal (SBEAT) systems for SBGR installations are flared to reduce nuisance impacts and also require special accommodations in roadside grading and drainage facilities. The relatively flat area should extend at least 1.5 m behind the terminal nose in a direction away from the road so errant vehicles impacting the terminal (right shoulder installation) with the left front of the vehicle will not reach a high roll angle prior to impact. Figure 4-32~~25~~ shows the desirable grading cross-sections for a new SBEAT installation along with flaring of the SBEAT.

Designers have the flexibility to extend the length of guide rail installations to a location where desirable grading requirements for a new SBEAT installation can be better accommodated.

Designers also have the flexibility to provide less than the desirable grading requirements for new end terminal installations when constrained by environmental or property restrictions. This may include reducing the desirable widening behind terminal post #1 and/or increasing the steepness of the slope behind the system. This should be documented in the project file.

Where the roadway is being widened for the installation of an~~d~~ SBEAT or SBT,~~,~~ drainage requirements need to be considered and addressed.

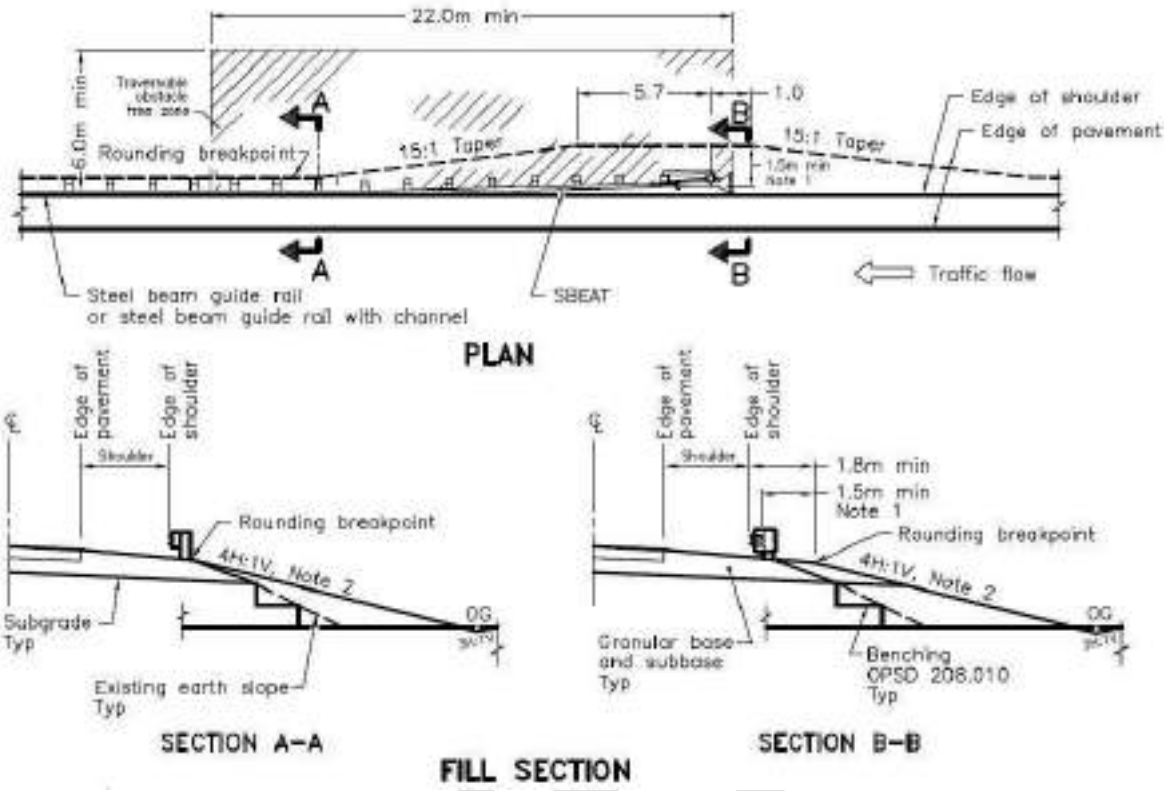


Figure 4-~~32~~27: Desirable Grading for SBEAT Installations

See applicable standard for Notes

4.4.1.2 Max Tension Terminal System

The MAX-Tension tangent end terminal is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3.

The system uses a tension-based design along with an energy absorbing coupler that features cutting tooth design. When impacted head-on, deceleration is controlled by friction developed in the tension cables and by cutting the downstream guide rail panels. When an angled side impact occurs beyond post 4, tension cables help the beams to redirect a motorist away from the obstacle being shielded along the system.

The MAX-Tension terminal uses many standard guide rail components such as steel posts, rails and offset blocks.

Figure 4-33~~28~~: MAX-Tension Terminal System
Photo courtesy of Lindsay Corporation

Manufacturer: Lindsay Corporation – Barrier Systems
Web Site: http://www.barriersystemsinc.com

4.4.1.3 SoftStop Terminal System

The SoftStop tangent end terminal is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3.

The system uses a tension-based design with a front anchor that is designed to allow the rail panels to remain anchored during end-on impacts. When an angled side impact occurs beyond post 3, the system redirects a motorist away from the obstacle being shielded along the system.

Figure 4-3429: SoftStop Terminal System

Manufacturer: Trinity Highway Products
Web Site: http://www.highwayguardrail.com

4.4.1.4 MASH Sequential Kinking Terminal System

The MASH Sequential Kinking Terminal (MSKT) system is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3.

The MSKT is a compression-based design which is an update to the Sequential Kinking Terminal (SKT) system that met NCHRP Report 350. During head-on impacts, the MSKT head slides over the W-beam guardrail and the rail is sequentially kinked as it moves through the impact head. The kinked guardrail exits the head behind the system away from the roadway and the vehicle is brought to a controlled stop. This is the same technology used by the SKT. Also similar to the SKT, angled impacts beyond post 3 are redirected along the system by the MSKT.

The MSKT impact head may be used for repairs of existing SKTs. However, use of the MSKT head on an existing SKT installation does not convert the existing SKT into a system that meets MASH. The MSKT also has a ground strut connecting posts 1 and 2 together at ground level, which the SKT does not use.

Figure 4-35~~0~~: MSKT Installation
Photo courtesy of Road Systems, Inc.

As with all compression based terminal systems (MSKT, SKT, Eccentric Loader Terminal, Extruder Terminal and CAT), the 20 cm x 20 cm bearing plate at post #1 needs to be correctly positioned with bolt located closer to bottom of plate (e.g., center of bolt is 12.5 cm below top of plate and 7.5 cm above bottom of plate) as shown in Figure 4-36~~29~~. It is acceptable to place a retainer/tie over the bearing plate to prevent rotation. The anchor cable is taut and correctly installed.

Figure 4-36~~31~~: Correct Orientation of Bearing Plate on Compression Based Terminals Photo courtesy of Road Systems, Inc.

Manufacturer: Road Systems Inc.

Web Site: http://www.roadsystems.com

4.4.1.5 SPIG Gating End Terminal

The Safety Products Innovations in Guardrail (SPIG) Gating End Terminal (SGET) system is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3. It was developed by SPIG Industries in Bristol Virginia.

During head-on impacts, the SPIG head engages the vehicle and impacts Post 1 which breaks away. The impact head then slides over the W-beam guiderail and the rail is flattened as it moves through the impact head while Posts 2 through 8 break away at ground level. The flattened guardrail exits the head behind the system away from the roadway and the vehicle is brought to a controlled stop. The system is gating-redirective, angled impacts beyond Post 3 are redirected along the system by the SGET.

Figure 4-37~~2~~: SPIG Gating End Terminal Installation
Photo courtesy of SPIG Industries

Manufacturer: SPIG Industries
Website: https://spigindustry.com/sget

4.4.1.6 MASH Next Generation Terminal System

The MASH Next Generation Terminal (NGT) System is a proprietary non-gating redirective energy absorbing, end terminal system that meets the crash test acceptance requirements of MASH TL-3. The system features a tension-based design utilizing a specialized impact head, high-strength cable anchoring system, a special first panel of W-beam guardrail, and plug-welded posts.

-

Figure 4-38~~XX~~: NGT System

Photo courtesy of NextGen Industries

The impact head serves as the primary control of energy absorption. During a head-on impact, the impact head moves along the W-beam guardrail, absorbing energy by reshaping the W-beam guiderail and allowing it to exit from the bottom of the assembly. When an angled side impact occurs beyond post 2, the system redirects a motorist away from the obstacle being shielded along the system.

The standard system configuration incorporates 10.5 m of the system length into the calculated length of need, being redirective starting at Post 2. As illustrated in Figure 4-39~~7~~, the system utilizes a 1905 mm half-length rail and a standard Type M rail downstream of the anchor panel. At constrained locations, the half-length rail and Post 11 may be omitted to reduce the length of need contribution to 8.6 m.

Although full-scale crash testing demonstrated redirective capability starting at Post 2, simulations indicate that the NGT has redirective capability starting at Post 1. In addition, it has been demonstrated to stop vehicles in head-on impacts at speeds up to 120 km/h, in excess of the standard MASH requirement of 100 km/h. For this reason, the NGT is classified as a High

Performance SBEAT and is a preferred system where available guiderail installation length is limited or at SBEAT locations experiencing a high volume of high speed impacts.

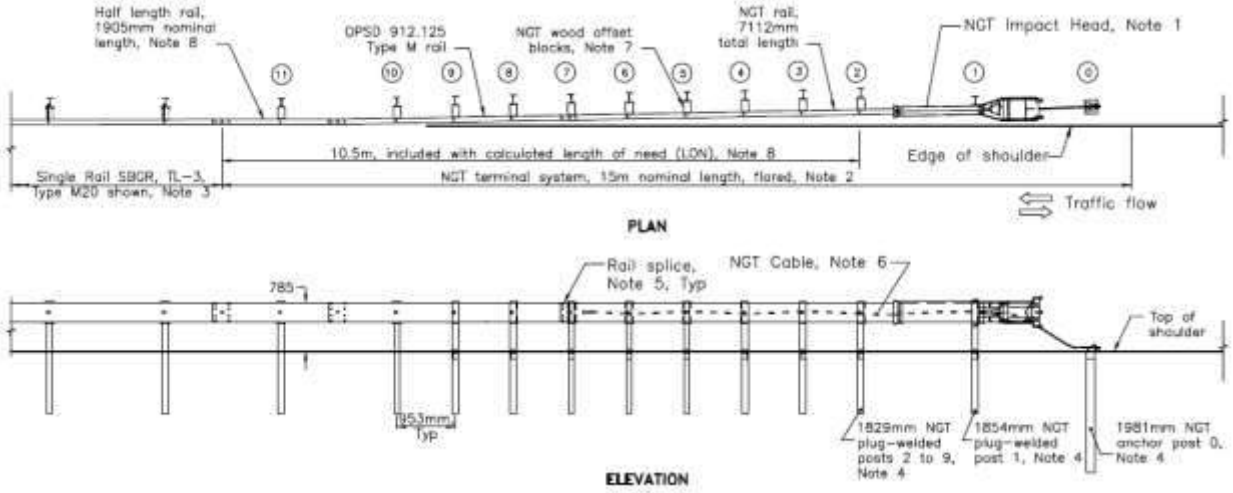


Figure 4-39~~XX~~: NGT System Installation

See applicable standards for note references.

Manufacturer: NextGen Industries
Web Site: https://www.nextgensafety.net/

4.4.1.7~~6~~ Max Tension Median Terminal

The MAX-Tension Median end terminal is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3. The system functions similarly to the roadside Max Tension system. The main difference between the two systems is the wider impact head which allows for termination of a double-sided 785 mm high guiderail system.

The system uses a tension-based design along with an energy absorbing coupler that features cutting tooth design. When impacted head-on, deceleration is controlled by friction developed in the tension cables and by cutting the downstream guide rail panels. When an angled side impact occurs beyond post 3, tension cables help the beams to redirect a motorist away from the obstacle being shielded along the system. The system has a ~~nomnal~~nominal length of 15.2 m~~etres~~ and contributes 12.4 m~~etres~~ to the length of need. The system should not be installed on curves.

The MAX-Tension Median terminal uses many standard guide rail components such as steel posts, rails and offset blocks.

Figure 4-4033: Max Tension Median Terminal Installation

Photo courtesy of Lindsay Corporation

Manufacturer: Lindsay Corporation – Barrier Systems
Web Site: http://www.barriersystemsinc.com

4.4.1.8~~7~~ Median Attenuating Trend Terminal

The Median Attenuating Trend Terminal or MATT is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3.

The system absorbs energy through a combination of rail shearing and post yielding. When impacted head-on, the rail segment is pushed back and past the blockout. The tabs punched in the rail engage with the blockout assembly and the steel between the tabs is sheared. Additionally, as a vehicle reaches a post, the upper portion breaks away from the lower portion. When an angled side impact occurs beyond post 2, the system redirects an impacting vehicle away from an obstacle being shielded by the system. The system has a nomnal length of 10.5 m~~etres~~ and contributes 6.6 m~~etres~~ to the length of need. The system should not be installed on curves.

Figure 4-41~~34~~: Median Attenuating Trend Terminal
Photo courtesy of Trinity Industries

Manufacturer: Trinity Industries
Web Site: http://www.trinityhighway.com

4.4.1.98 Slotted Rail Terminal

The Slotted Rail flared end Terminal (SRT) is a proprietary gating non-energy absorbing, end terminal system that meets the crash test acceptance requirements of MASH TL-3.

The system is installed with a 10:1 (5.7^0) flare with rail at post #1 offset 1.22 m away from the shoulder. The nominal system length is 12.4 metres and the system contributes 6.7 metres to the length of need.

When an angled side impact occurs beyond post 4, the system redirects a motorist away from the obstacle being shielded along the system.

This system is acceptable for Steel Beam Terminal (SBT) item and is typically specified for use on provincial highway projects where Type M SBGR starts on either the inside or outside edge of a horizontal curve with centerline radii less than 190 m.

Figure 4-4235: Slotted Rail Terminal
Photo courtesy of Trinity Highway Products

Manufacturer: Trinity Highway Products
Web Site: http://www.highwayguardrail.com

4.4.1.109 MASH Flared Energy Attenuating Terminal

The MASH Flared Energy Attenuating Terminal (MFLEAT) is a proprietary gating energy absorbing, end terminal system that meets the crash test acceptance requirements of MASH TL-3.

The system is installed with a 13:1 (4.3^0) flare with rail at post #1 offset 0.91 m away from the shoulder. The system may be installed at an offset of 1.22 m from the shoulder provided the flare rate of 13:1 is maintained. This requires the start of the flaring to be extended further down the length of the guiderail. The nominal length of the MFLEAT is 12.4 m ~~etres~~ and the system contributes 7.3 m~~etres~~ to the length of need.

When an angled side impact occurs beyond post 4, the system redirects a motorist away from the obstacle being shielded along the system.

This system is acceptable for Steel Beam Terminal (SBT) item and is typically specified for use on provincial highway projects where Type M SBGR starts on either the inside or outside edge of a horizontal curve with centerline radii less than 190 m.

Figure 4-4336: MASH Flared Energy Attenuating Terminal
Picture courtesy of Road Systems Inc

Manufacturer: Road Systems Inc.
Web Site: http://www.roadsystems.com

4.4.2 Crash Cushions

Crash cushions are classified into the following categories based on their behavior upon impact:

- Redirective, gating;
- Redirective, non-gating; or
- Non-redirective, gating.

A redirective, gating crash cushion allows a vehicle impacting the side of the unit at an angle, near the nose, to pass through the crash cushion. In head-on impacts, a redirective, gating crash cushion should bring the impacting vehicle to a controlled stop. The beginning of length of need of a redirective, gating crash cushion varies, depending on the specific crash cushion employed. For impacts within the length of need (e.g. downstream of the gating nose portion of the crash cushion), a gating, redirective crash cushion has similar redirectional characteristics as a standard roadside barrier.

A redirective, non-gating crash cushion is capable of redirecting a vehicle impacting the side of the crash cushion at an angle along the unit's entire length. In head-on impacts, a redirective, non-gating crash cushion should bring the impacting vehicle to a controlled stop. The length of need of a redirective, non-gating crash cushion starts from the nose. For impacts within the length of need, a redirective, non-gating crash cushion has the same redirectional characteristics as the adjacent barrier system.

A non-redirective, gating crash cushion cannot redirect vehicles impacting anywhere along its length. In head-on impacts, a non-redirective, gating crash cushion should bring the impacting vehicle to a controlled stop. Vehicles impacting the sides of a non-redirective, gating crash cushion at an angle may either be contained, proceed through the crash cushion or be deflected, depending on their impact angle, impact point, speed, and weight.

4.4.2.1 Summary of Crash Cushions

The crash cushions (energy attenuators) currently accepted and specified for installation as permanent systems on provincial highway projects are listed in Table 4-3.

Energy Attenuator	NCHRP Report 350 or AASHTO MASH Crash Test Level		Permanent Installation					
	TL-2	TL-3	Narrow (NA)	Wide (WI)	Extra Wide (EW)	Super Wide (SW)	High Exposure (HE)	Single Sided (SS)
TAU-M System (Note 1)	Yes	Yes	Yes	No	No	No	No	No
TAU-II Wide System (Note 2)	Yes	Yes	No	Yes	No	No	No	No
TAU-II Extra Wide System	Yes	Yes	No	No	Yes	No	No	No
Quadguard M10 System (Note 1)	Yes	Yes	Yes	No	No	No	No	No
Quadguard M10 Wide System (Notes 1 and 2)	N/A	Yes	No	Yes	No	No	No	No
Quadguard Wide System (Note 2)	Yes	Yes	No	Yes	No	No	No	No
Quadguard Extra Wide System	Yes	Yes	No	No	Yes	No	No	No
Quadguard Super Wide System	No	Yes	No	No	No	Yes	No	No
Delta System	Yes	Yes	Yes	No	No	No	No	No
~~QuadTrend~~	~~No~~	~~Yes~~	~~No~~	~~No~~	~~No~~	~~No~~	~~No~~	~~Yes~~
~~BB-Beat~~	~~No~~	~~Yes~~	~~No~~	~~No~~	~~No~~	~~No~~	~~No~~	~~Yes~~
Smart System (Note 1)	Yes	Yes	Yes	No	No	No	Yes	No
Hercules System (Note 1)	N/A	Yes	Yes	No	No	No	No	No

Note:
1. AASHTO MASH crash test compliant system.

2. The Quadguard M10 Wide (meeting AASHTO MASH TL-3) shall be used for Permanent Unidirectional configurations requiring a TL-3 crash test compliant system. For Permanent Unidirectional configurations requiring a TL-2 crash test compliant system and for all Bidirectional configurations of Energy Attenuator, Wide, systems listed on Table 1 and meeting NCHRP Report 350 shall be used.

Table 4-3: Permanent Energy Attenuators

Test Level and Posted Speed:

Crash cushions accepted for use on the provincial highway system should meet the crash test acceptance requirements of AASHTO MASH test levels 2 or 3 (TL-2 or TL-3). NCHRP Report 350 systems may still be listed if ~~not~~ MASH compliant systems were not yet implemented due to

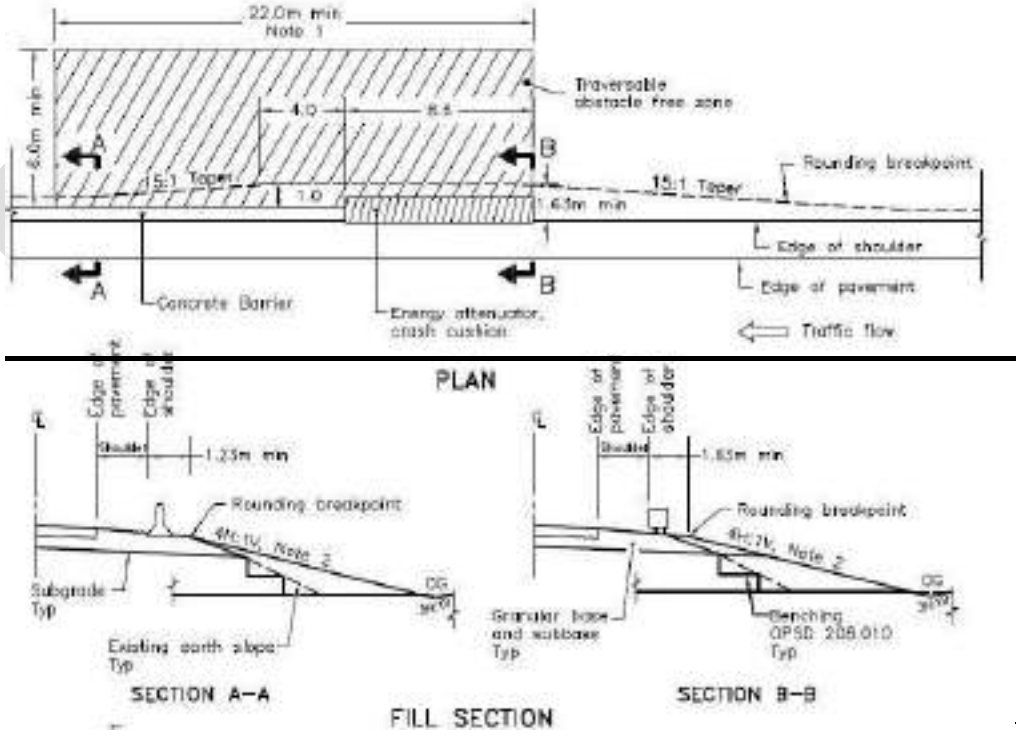
availability. Examples of the continuous use of legacy systems include wide, extra wide and super wide systems. The list of permanent energy attenuators is updated frequently. Designers should find the latest list in the ministry's contract preparation system. For convenience, the latest list is also found in the MTO Technical Publications website.

For each crash cushion installation, the appropriate test level should be determined based on the posted speed of the roadway. TL-2 configurations are specified for low-speed installations with posted speeds of less than 70 km/h. TL-3 configurations are specified for high-speed installations with posted speeds of 70 km/h and greater.

~~Redirective, Gating Systems~~

~~The systems listed under the Single Sided column in Table 4-3 are redirective, gating Crash Cushions and are specified for permanent installations only. These crash cushions should be used in locations where vehicles will impact the system from one side only, typically on roadside shoulders. A traversable area free of fixed obstacles is required behind and beyond the system as shown in Figure 4-35.~~

~~Desirable grading, as shown in Figure 4-35 should be used at all installations of redirective, gating crash cushions.~~



~~Figure 4-37: Desirable Grading for Single Sided Energy Attenuating Terminals~~

~~Redirective, gating crash cushions should not be installed in a location where backside impacts are possible (e.g., in gore areas), or in a narrow medians where backside, opposite direction impacts are possible.~~

~~Redirective, gating systems are currently only available in a TL-3 configuration.~~

Redirective, Non-Gating Systems:

The systems listed under the Narrow, Wide, Extra Wide, Super Wide and High Exposure columns in Table 4-3 are redirective, non-gating crash cushions. Following a design impact, these systems can typically be repaired. However, major component replacement may be required in order to make the entire system crashworthy again.

The QuadGuard, QuadGuard M-10, Tau-II, TAU-M and Smart crash cushions are specified for permanent and temporary use.

The Smart system listed under the High Exposure column in Table 4-3 is specified for locations where there is a high risk of impact such as in the gore of a core / collector transfer. The Smart 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. The Smart system has been proven to be the least expensive of all crash cushions specified by MTO to repair after design impacts, typically just requiring replacement of two shear bolts after the system is pulled back.

All of the accepted and specified redirective, non-gating systems can be installed in unidirectional and bidirectional configurations. Two narrow crash cushions placed side by side are not an acceptable equivalent to a wider crash cushion.

Redirective, non-gating systems are available in TL-2 and TL-3 configurations.

Unidirectional versus Bidirectional:

The term “unidirectional” describes an installation where traffic flow passes the energy attenuator system on one or both sides in the same direction from the upstream direction of travel (i.e., approaching the impact head of the energy attenuator). -For unidirectional installations, there is no requirement for a transition panel to connect the energy attenuator to the concrete barrier because reverse direction impacts are not expected. -Examples of unidirectional installations include but are not limited to roadside shoulder installations on divided highways and one way ramps as well as gore areas at freeway exit ramps or core collector transfers.

The term “bidirectional” describes an installation where traffic flow passes the energy attenuator in the reverse / opposing direction of travel (i.e., approaching the leaving end / corner of the energy attenuator immediately adjacent to the concrete barrier). For bidirectional installations, there is a requirement for the contractor to install a transition panel to connect the energy attenuator to the concrete barrier in order to minimize the risk of a reverse direction impact snagging upon the rearmost fender panel of the energy attenuator. Examples of bidirectional installations include but are not limited to undivided highways and narrow medians where reverse direction impacts are possible.

Terrain and Foundation Requirements:

Crash Cushions are typically tested on paved, flat and level terrain. It is desirable to install crash cushions on relatively flat terrain, and the traversable area between the travelled portion of the roadway and the device should be free of obstacles and irregularities. Approaches to the crash cushion should be 10H:1V or flatter. A traversable area, free of significant fixed objects, should be provided adjacent and beyond the crash cushion.

Crash cushions should not be placed on surfaces with a crossfall greater than 6%.

All permanent crash cushions should be installed on a new reinforced concrete pad, with the exception of the Box Beam Bursting Energy Absorbing Terminal, which is installed on driven steel posts into compacted granular base. If an existing concrete surface or pad can be used to support the crash cushion, its surface must be in good condition in order to accommodate installation of anchors for the system.

Temporary crash cushions may be anchored to existing concrete surfaces, asphalt over compacted granular, or to asphalt over concrete. The existing surface must be in good condition in order to provide a smooth operating surface. The following dimensions represent the minimum foundation requirements for temporary crash cushion installation:

- Existing Concrete Surface:
  - Minimum 200 mm deep concrete with 28 MPa minimum compressive strength.
- Asphalt over Compacted Granular:
  - Minimum 150 mm asphalt over a minimum 150 mm compacted granular.
  - The asphalt must extend a minimum of 500 mm beyond the anchor bolts.
- Asphalt over Concrete:
  - Minimum 75 mm asphalt over a minimum 75 mm concrete with 28 MPa minimum compressive strength.

Where temporary crash cushions are required to be placed on the inside of horizontal curves, the geometry of the proposed location should be checked to ensure that the crash cushion, and downstream barriers placed tangent to the crash cushion, will not result in excessive encroachment of the crash cushion into the shoulder or any encroachment into the travelled lane when installed. If such a conflict is identified, alternative locations should be considered which may require lengthening of a temporary construction barrier run or an alternative staging arrangement.

Curb and Gutter:

Crash cushions should not be installed within close proximity to barrier curb and gutter. Where curb and gutter is required, mountable curb should be used starting approximately 15 m in front of the crash cushion and as far back as the system's backup.

Delineation of Crash Cushions:

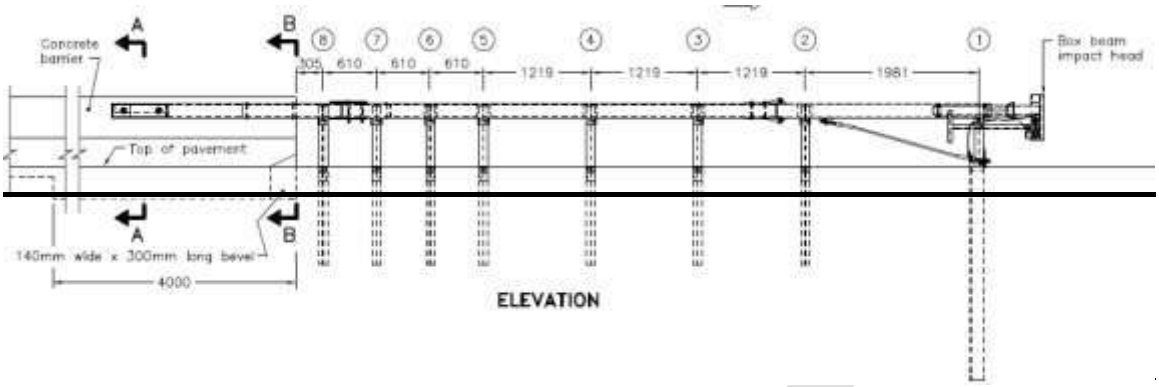
A crash cushion typically does not reduce the frequency of impacts. The intent of a crash cushion is to lessen the severity of impacts when they do occur. However, delineation of the crash cushion may provide some reduction in the frequency of collisions with crash cushions.

Each permanent and temporary crash cushion installation should include appropriate delineation. For permanent installations, delineation should include a standard object marker and snow plow marker. For temporary installations, delineation should include a standard object marker and snow plow marker as well as flexible delineator posts when the crash cushion is located in a gore area or in a location where the shoulders are less than 2.0 m in width.

When installed on a paved surface, the signs should be mounted on a surface mounted flexible post. When installed on a granular surface, the signs should be mounted on a steel U channel post.

~~4.4.2.2 Box Beam Bursting Energy Absorbing Terminal~~

~~The Box Beam Bursting Energy Absorbing Terminal (BB-BEAT) System is a proprietary redirective, gating, single-sided crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-3.~~



~~Figure 4-38: Box Beam Bursting Energy Absorbing Terminal~~

~~For head on impacts, the system absorbs energy in three stages. The impact head will engage the front of the vehicle and will be pushed forward along the stage one box beam rail element. The impact head will then contact the post breaker beam and break off the first steel breakaway post, releasing the cable anchorage. The tapered mandrel will split the box beam. If the vehicle has sufficient energy, it will continue into the stage two box beam rail element in the same manner, progressively splitting the box beam as the vehicle moves along. The system is designed to dissipate the energy from a 2000 kg pick up truck within the first two stages. However, additional capacity is provided by the third stage box beam rail element.~~

~~When the BB-BEAT is hit at an angle between the impact head and the third post, the impacting vehicle will gate through the system in a controlled manner and travel in behind the system before coming to rest.~~

~~The cable anchorage system provides the necessary tensile strength in the box beam rail to resist and redirect impacts downstream of the third post.~~

~~The BB-BEAT is typically used to shield the ends of concrete roadside barriers. It should only be used in locations where vehicles will impact the system from one side only. The BB-BEAT is acceptable and specified for permanent use only as a single sided crash cushion for permanent installations.~~

~~Manufacturer: Road Systems, Inc.~~
~~Web Site: http://www.roadsystems.com/~~

~~4.4.2.3 QuadTrend 350 End Treatment System~~

~~The QuadTrend is a proprietary redirective, gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-3.~~

~~Figure 4-39: QuadTrend Terminal~~

~~The system is 5.87 m in length. The post slip bases are anchored to a reinforced concrete pad and the rear end of the system is anchored to the concrete barrier wall using an offset transition panel. The front end of the redirecting cable is anchored to the concrete foundation in front of the first post. The rear end of the redirecting cable is routed through the first post and then extends at an angle of 25 degrees away from the system to an anchor block located 3.0 m behind the system on the roadside slope.~~

~~For head on impacts, the system simultaneously collapses and moves laterally along the redirecting cable to redirect an impacting vehicle away from the end of the concrete barrier. As the system collapses, the Quad-Beam fender panels telescope rearward and the posts shear at the slip bases. The sand-filled containers help dissipate collision energy. The Quad-Beam fender panels redirect the vehicle away from the hazard during side and reverse direction impacts. The QuadTrend System is typically used to shield the ends of concrete roadside barriers.~~

~~The QuadTrend should be used in locations where vehicles will impact the system from one side only. This will typically include roadside shoulders where there is there is sufficient space to provide an area behind and beyond the system that is traversable and free of fixed obstacles for a width of 6.0 m and a length of 22.0 m. The QuadTrend System is acceptable and specified for permanent use only as a single sided crash cushion for permanent installations.~~

~~Manufacturer: Energy Absorption Systems, Inc.~~
~~Web Site: http://www.energyabsorption.com~~

4.4.2.4 QuadQuard and QuadGuard M10 Systems

The QuadGuard System is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3. The QuadGuard M10 version of the system meets the requirements of MASH TL-2 and TL-3.

The system consists of a series of energy-absorbing cartridges supported by a framework of steel diaphragms and Quad-Beam fender panels. The self-supporting nose consists of a formed plastic wrap and an energy-absorbing cartridge. The system uses a centre monorail base that resists lateral movement during side impacts and a tension strut backup structure that anchors the system and resists movement during head-on impacts. The monorail base and tension strut backup are anchored to the foundation.

Figure 4-4~~0~~: QuadGuard M-10
Photo courtesy of Energy Absorption Systems, Inc.

For head on impacts, the cartridges absorb the impact energy while the fender panels telescope rearward on the diaphragms that slide along the monorail base as the system collapses. The tension strut backup provides anchorage for the system.

The QuadGuard System is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The QuadGuard System is acceptable and specified for permanent and temporary use.

The narrow system is typically used to shield the ends of concrete barrier. The wide and extra wide systems are typically used to shield the ends of two runs of concrete barrier that meet at gore or median locations or for shielding fixed objects such as bridge piers.

Currently the Quad Guard M10 is only available as a narrow or permanent, unidirectional wide system. The QuadGuard system shall continue to be used for temporary and bidirectiona wide, extra wide and super wide applications. See Table 4-3 for details.

Manufacturer: Energy Absorption Systems, Inc.
Web Site: http://www.energyabsorption.com/index.asp

4.4.2.5 SMART Cushion

The Smart System is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3, and was subsequently crash tested without any modifications to MASH TL-3.

Figure 4-45~~1~~: SMART Unidirectional Crash Cushion

For head on impacts, the system telescopes rearward as the side panels slide one over the next. The system is speed dependent and stops small vehicles by the hydraulic ram automatically regulating the stopping force exerted on the vehicle. Therefore, small vehicles are stopped at a slower rate than larger vehicles. This minimizes the deceleration forces on the vehicle occupants.

The Smart Cushion is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The Smart Cushion is acceptable for permanent and temporary use.

The Smart Cushion is categorized as a low maintenance system that is suitable to locations where there is high exposure and risk of impact such as in the gore of a core/collector transfers. Following most head on impacts, a trained repair crew can reset an impacted Smart Cushion in 30 to 60 minutes. In addition, it has been documented that more than 80% of Smart Cushion

repairs required replacement of only the two shear bolts. In side impacts, the fender panels often receive little to no damage. As a result, repair crew exposure to traffic and motorist inconvenience is typically minimized as well as repair cost.

Manufacturer: SCI Products, Inc.
Web Site: http://workareaprotection.com/attenuators/

4.4.2.6 TAU-II and TAU-M Systems

The TAU-II System is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3. The TAU-M version meets the crash test acceptance requirements of MASH TL-2 and TL-3.

The system consists of a series of energy absorbing cartridges supported by a framework of steel diaphragms and telescoping thrie beam side panels.

The nose consists of a formed plastic wrap. The system uses two cables to resist lateral movement during side impacts and a compact backstop structure that anchors the cables and resists movement during head-on impacts.

The cables are attached to the compact backstop at the rear of the system and anchored to the foundation at the front of the system. The compact backstop is anchored to the foundation. The cables pass through the diaphragms, which are not anchored to the foundation.

Figure 4-462: TAU-M Narrow System

For head on impacts, the cartridges absorb the impact energy while the fender panels telescope rearward on the diaphragms that slide along the cables as the system compresses. The compact backstop(s) and front cable anchor(s) are bolted to the reinforced concrete pad according to manufacturer guidelines. The fender panels, diaphragms, and cables redirect vehicles during side and reverse direction impacts.

The TAU-M system is currently only available for narrow installations. For wide and extra wide applications, the TAU-II system shall continue to be used. See Table 4-3 for additional information.

Manufacturer: Lindsay Transportation Solutions
Web site: https://www.lindsay.com/

~~Manufacturer: Barrier Systems Inc.~~
~~Web site: http://www.barriersystemsinc.com/~~

4.4.2.7 SMA Hercules

The SMA Hercules system is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of MASH TL-3.

The system consists of a series of all-steel collapsible beams, split into ten bays which slide on a steel base rail which is in turn fastened to a steel base plate. A frontal sliding trolley sits at the upstream end of the system and functions as the nose. The base and rail as well as the 4-beam side panels resist lateral movement during side impacts and a backstop anchors the system and resists movement during head-on impacts. The steel base and backstop are anchored to the foundation.

Figure 4-4~~7~~3: SMA Hercules

For head on impacts, the frontal sliding trolley is pushed along the rail into the collapsible beams which absorb the impact energy as the system collapses. The supports which connect the beams to the base collapse, also dissipating impact energy. The backstop provides anchorage for the system.

The SMA Hercules is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The SMA Hercules is acceptable and specified for permanent and temporary use.

Currently the SMA Hercules is only available as a narrow system, and only in a TL-3 configuration although it is appropriate for low-speed installations as well.

Manufacturer: Safety Modular Absorber
Web site: http://www.smaroadsafety.com

4.4.2.8 Delta Crash Cushion

The Delta system is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of MASH TL-3.

The system consists of a series of thrie beam fender panels supported by a framework of steel diaphragms. The nose piece is attached to the front of the system using four bolts. The dual rail base resists lateral impacts. The base of the system is anchored to the foundation.

Figure 4-484: Delta Crash Cushion

For head on impacts, a series of shear bolts tears through pre-punched cut-outs in the sides of the thrie beam panels, dissipating the impact energy.

The Delta system is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The Delta system is acceptable and specified for permanent and temporary use.

Currently the Delta is only available as a narrow system, and only in a TL-3 configuration although it is appropriate for low speed installations as well.

Manufacturer: Traffix Devices
Website: https://www.traffixdevices.com/products/attenuators/delta~~Website: https://www.traffixdevices.com/products/attenuators/delta~~

4.4.2.9 TAU-XR System

The TAU-XR System is a proprietary redirective, non-gating crash cushion that meets the crash test acceptance requirements of the AASHTO Manual for Assessing Safety Hardware (MASH) for TL-3.

The system consists of a series of energy collapsible bays equipped with varying arrays of crushable aluminum tubes and supported by a framework of steel mid-supports and telescoping thrie-beam side panels. The nose consists of a hollow box formed by square steel tubes bolted together, with an attached hazard placard. The base of the system is anchored to a reinforced concrete foundation.

Figure 4-49: TAU-XR Narrow System

For head on impact, the crushable aluminum tubes absorb the kinetic energy and safely contain vehicles while the system telescopes rearward as the side panels slide one over the next. The side panels are also intended to safely redirect vehicles impacting along the side of the system.

The TAU-XR system is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The system is acceptable for permanent and temporary use.

The TAU-XR system is currently only available for narrow installations. For wide and extra wide applications, the TAU-II system shall continue to be used. See Table 4-3 for additional information.

Manufacturer: Lindsay Transportation Solutions
Web site: https://www.lindsay.com/

4.4.3 Barrier System Transitions and Connections

Transitions between different barrier systems are designed to withstand vehicle impacts in the vicinity of the transition between barrier systems of differing rigidity, shape, mounting height, and performance characteristics. This is typically accomplished in a gradual manner because abrupt changes in barrier characteristics such as rigidity or shape could result in a vehicle pocketing or snagging in the vicinity or the transition.

Standard transition designs are available for use on Provincial Highways. Transitions are designed for either one-way or two-way traffic. Care must be taken to ensure that the appropriate standard transition is selected.

~~4.4.2.9 TAU-XR System~~

~~The TAU-XR System is a proprietary redirective, non-gating crash cushion that meets the crash test acceptance requirements of the AASHTO Manual for Assessing Safety Hardware (MASH) for TL-3.~~

~~The system consists of a series of energy collapsible bays equipped with varying arrays of crushable aluminum tubes and supported by a framework of steel mid-supports and telescoping thrie-beam side panels. The nose consists of a hollow box formed by square steel tubes bolted together, with an attached hazard placard. The base of the system is anchored to a reinforced concrete foundation.~~

~~Figure 4-XX: TAU-XR Narrow System~~

~~For head-on impact, the crushable aluminum tubes absorb the kinetic energy and safely contain vehicles while the system telescopes rearward as the side panels slide one over the next. The side panels are also intended to safely redirect vehicles impacting along the side of the system.~~

~~The TAU-XR system is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The system is acceptable for permanent and temporary use.~~

~~The TAU-XR system is currently only available for narrow installations. For wide and extra wide applications, the TAU-II system shall continue to be used. See Table 4-3 for additional information.~~

~~Manufacturer: Lindsay Transportation Solutions~~

~~Web site: https://www.lindsay.com/~~

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4.4.4 Existing In-Service Systems

End terminal and crash cushion design has evolved over the past 40 years along with crash test acceptance criteria. Road authorities, including the ministry, are continually updating and/or implementing standard designs for new hardware.- As such, the existing in-service road safety hardware systems represent a broad range of performance characteristics, reflecting the standards-of-the-day when each was installed. While some systems may not meet the current testing procedure, existing in-service systems should still continue to perform on the provincial highway system and may remain in-service until the end of their service lives. An exception to this is for systems that were crash tested according to procedures that predate NCHRP Report 350, such as NCHRP Report 230 and its predecessors. Such systems, though now rare on the provincial highway network, are approximately 30 years old at a minimum and may have deteriorated plastic, steel and anchoring components and should be replaced with currently specified system on all capital projects.

4.5 Poles and Sign Support Systems

The Ministry specifies sign support systems based on sign material, dimensions, and total assembly area, including any attached tabs. In general, breakaway supports are mandatory unless the installation is located beyond the clear zone or shielded from traffic by a barrier. All new permanent sign supports must meet the crash test acceptance requirements of NCHRP Report 350 Test Level 3 (TL-3), ensuring they fail predictably during head-on impacts by both small vehicles and pick-up trucks while maintaining vehicle stability and minimal cabin intrusion. Additionally, these systems are designed to withstand wind speeds of 110 km/h (70 mph) and comply with wind load/pressure requirements for a ten-year return period in Ontario per the Canadian Highway Bridge Design Code. While MASH-compliant systems are currently being tested, MTO standards will be updated as these new systems are formally accepted for provincial use.

All sign installations are intended for traversable roadsides with sideslopes of 3H:1V or flatter and assume placement in competent soils of uniform composition. If site conditions involve rock cut, rock fill, or exceptionally soft soil, a modification to the foundation design or an alternative support system is required. To maintain roadside safety and drainage integrity, posts must be offset more than 1.5 m from the bottom of drainage ditches and must not be installed within the 22 m x 6 m obstacle-clear area located beyond guide rail terminal systems. When signs are placed behind a barrier, they must be offset beyond the system's specified working width. New barrier systems shall not be installed or extended for the sole purpose of protecting large sign support assemblies if a breakaway design is practical or if the sign can be relocated behind existing shielding.

The physical geometry of the installation is critical to preventing secondary hazards during a collision. The bottom of the sign must be mounted at a minimum height of 2.1 m above the ground, measured vertically at each post, to allow an errant vehicle to pass safely under the sign board. Furthermore, for assemblies requiring two or more posts, the clearance between them must be at least 2.1 m. This spacing is based on the average width of a passenger vehicle and is intended to minimize the probability of a single vehicle impacting two posts simultaneously. Posts may only be spaced closer than 2.1 m if that specific configuration has been crash-tested and approved.

All large sign assemblies consisting of extruded aluminum sign panels generally 2.4 m and wider with total sign areas ranging from 2.9 m^2 to 23.8 m^2 installed on capital construction contracts on provincial highways should have been designed and installed according to the latest edition of the Ontario Traffic Manual (OTM) Book 3. OTM Book 3 provides standards and guidelines for the design of large aluminum extruded signs on wood column and steel column breakaway and non-breakaway sign support structures for various sizes of sign assemblies on various slopes. OTM Book 3 provides standard drawings for each sign support structure which require the design and completion of fill-in tables and dimensions, and shall bear the seal, date and signature of a Professional Engineer. These installations should be breakaway unless being installed behind an appropriate length of existing barrier systems offset appropriately to accommodate barrier working width. For additional details for design and installation of large sign support systems, refer to the latest edition of OTM Book 3.

Large overhead signs and cantilever signs on high-speed highways should be located behind an appropriate length of existing barrier system offset appropriately to accommodate barrier working width. Overhead and cantilever signs mounted on a crashworthy median or roadside barrier may be shielded with a redirective, non-gating crash cushion with an appropriate width and transition detail. These signs should be designed according to the latest edition of the Sign Support Manual.

Installers are responsible for selecting the appropriate wooden and/or steel sign support system standard for each installation based on the specific sign dimensions and total area. To aid in selection, Figure 4-50~~XX~~ shows the three permanent ground mounted sign support system types, listing acceptable sign materials for each system against sign assembly area ranges for each system.

~~Since 2011, all new permanent small sign support systems installed on capital construction contracts on high speed provincial highways should have been breakaway and met the crash test acceptance requirements of NCHRP Report 350 TL-3 unless located behind an appropriate length of existing barrier offset appropriately to accommodate barrier working width. When signs are located behind an appropriate length of barrier, or for low-speed urban installations are located behind barrier curb, both breakaway or non-breakaway small sign support systems are acceptable.~~

~~Since March 2, 2017, all new permanent intermediate sign support systems installed on capital construction contracts on high speed provincial highways should have been breakaway and met the crash test acceptance requirements of NCHRP Report 350 TL-3 unless located behind an~~

~~appropriate length of existing barrier offset appropriately to accommodate barrier working width.~~

~~Since the late 1980s, all large sign assemblies consisting of extruded aluminum sign panels generally 2.4 m and wider with total sign areas ranging from 2.9 m^2 to 23.8 m^2 installed on capital construction contracts on provincial highways should have been designed and installed according to the latest edition of the Ontario Traffic Manual (OTM) Book 3. OTM Book 3 provides standards and guidelines for the design of large aluminum extruded signs on wood column and steel column breakaway and non-breakaway sign support structures for various sizes of sign assemblies on various slopes. OTM Book 3 provides standard drawings for each sign support structure which require the design and completion of fill-in tables and dimensions, and shall bear the seal, date and signature of a Professional Engineer. These installations should be breakaway unless being installed behind an appropriate length of existing barrier systems offset appropriately to accommodate barrier working width. For additional details for design and installation of large sign support systems, refer to the latest edition of OTM Book 3.~~

~~New barrier systems should not be installed or extended on provincial highway projects for the sole purpose of protecting new or relocated large sign support assemblies when design of breakaway sign support systems are practical and/or sign could be located elsewhere behind an appropriate length of existing barrier offset appropriately to accommodate barrier working width.~~

~~Large overhead signs and cantilever signs on high speed highways should be located behind an appropriate length of existing barrier system offset appropriately to accommodate barrier working width. Overhead and cantilever signs mounted on a crashworthy median or roadside barrier may be shielded with a redirective, non-gating crash cushion with an appropriate width and transition detail. These signs should be designed according to the latest edition of the Sign Support Manual.~~

~~Figure 4-43 shows the three permanent ground mounted sign support system types listing acceptable sign materials for each system against sign assembly area ranges for each system.~~

~~Many breakaway sign support systems are currently being crash tested according to MASH. MTO standards will be updated as MASH-compliant systems are accepted for use on provincial highways.~~

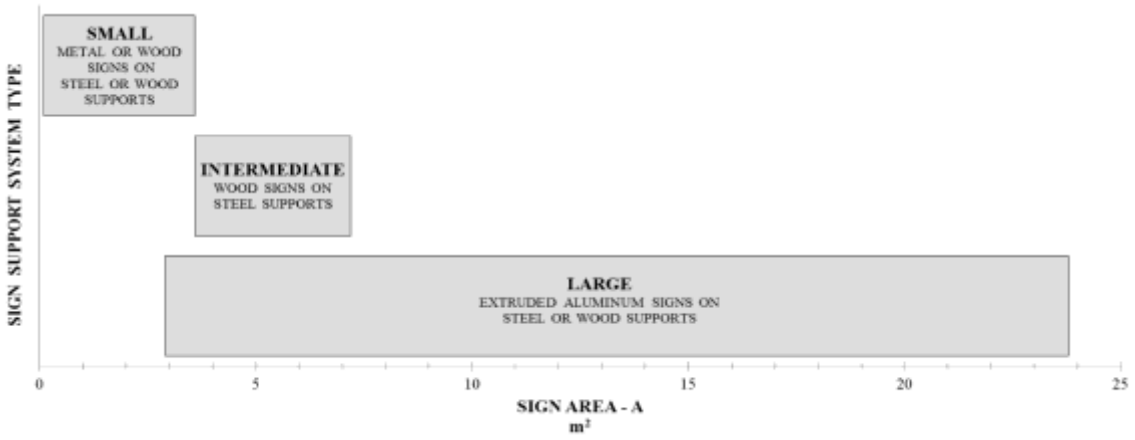


Figure 4-50~~XX45~~: Sign Support System Types and Sign Areas

4.5.1 Small Sign Support Systems

~~Although small signs are not always perceived as particularly hazardous, small signs can cause significant damage to impacting vehicles. Small and intermediate breakaway sign support system standards were developed for various sign sizes typically used on provincial highways.~~

~~Each standard sign support system met the crash test acceptance requirements of NCHRP Report 350 Test Level 3 and designed for wind speeds of 110 km/h (70 mph), and wind load/pressure requirements for a ten-year return period in Ontario according to the Canadian Highway Bridge Design Code.~~

Small Sign Assembly consist of one or more signs mounted on a sign support system with specified sign hardware, where total sign or sign board area does not exceed 3.6 m².

Permanent small ground mounted signs are typically constructed of metal or plywood and are supported on either breakaway or non-breakaway support systems. These systems utilize configurations of one or two wood posts, or one, or two, or three metal posts. Small signs can measure up to 2.4 m wide and 1.5 m high, provided the maximum area remains within the 3.6 m² limit.

Breakaway sign support systems are acceptable for use on both high speed and low speed roadways. Conversely, non-breakaway sign support systems with steel posts are specifically designed to resist wind loading and will bend upon impact are only acceptable on low-speed roadways (less then 70 km/h) equipped with barrier curb. The sign must not exceed 90 cm wide by 90 cm high, with a total area (including tabs) no greater than 0.56 m².

General details and dimensions for permanent ground-mounted small sign support systems—including single and double wooden post configurations or single, double, or triple steel post configurations—can be found in the applicable standards active in the MTO's Contract Preparation System (CPS).

4.5.1.1 Wooden Sign Support Breakaway System

The Wooden Sign Support Breakaway System is a non-proprietary system that meets the crash test acceptance requirements of NCHRP Report 350, Test Level 3. The system is adaptable to either single or double post arrangements, utilizing an array of dressed timber sizes and drilled hole diameter tailored to each configuration. For the standard 89 mm x 89 mm posts, the material is designed to fracture at ground level upon vehicle impact without additional modification.

For larger post dimensions, the assembly requires precision-drilled holes located at heights of 75 mm and 375 mm above the finished grade. These drilled holes are designed to weaken the timber in shear to ensure a fracture at ground level while maintaining sufficient moment capacity to resist specified wind loads. Depending on the sign size and configuration, posts are direct buried to a depth ranging from 920 mm to 1200 mm.

In a double post configuration, the 89 mm x 89 mm and drilled 89 mm x 140 mm pressure-treated systems are set no more than 2.1 m apart, measured from the outside face of each post. However, for larger dressed sizes, specifically 140 mm x 140 mm and 140 mm x 184 mm, the maximum 2.1 m spacing is measured from the inside face of each post to ensure compliant breakaway performance.

~~NCHRP Report 350 requires the sign support system to fail in a predictable manner when impacted head-on by a small vehicle at 35 km/h and at 100 km/h, and by a pick-up truck at 100 km/h. For acceptance, the crash tested vehicle needs to remain upright during and after the impact with minimal deformation or intrusion into the passenger compartment.~~

~~In general, the bottom of the sign needs to be mounted at a minimum height of 2.1m above the ground (measured vertically at each post) to allow errant vehicles to pass under the sign during an impact. As the average passenger vehicle is less than 2.1 m wide, when two or more posts are required for larger sign assemblies, the clearance between them should be 2.1 m or greater to minimize the probability of an errant vehicle of impacting two posts at same time. Support system posts may be located closer together than 2.1 m when they have been crash tested in that configuration as specified in the applicable standards.~~

~~Wooden sign support system posts of specified species and grade measuring 89 mm x 89 mm are designed to fracture near ground level during a passenger vehicle impact. Larger wooden posts need to be drilled perpendicular to the roadway at a height of 75 mm and 375 mm above the ground to weaken them in shear to ensure they fracture near ground level while maintaining moment capacity to resist wind loads. Figure 4-44 shows proper orientation of drilled holes that are specified in the applicable standards for small sign support systems with wooden posts.~~

~~For wood support systems, 89 mm x 89 mm (nominal 4” x 4”) and drilled 89 mm x 140 mm (nominal 6” x 6”) direct buried non-proprietary pressure treated wood post systems have been successfully crash tested in single and double post configurations. The posts are direct buried a minimum of 920mm or 1200mm into the ground, dependent on size and configuration. For these size posts in double post configurations, they are set no more than 2.1 m apart when measured from outside face of each post as shown in Figure 4-44. For larger drilled 140 mm x 140 mm or drilled 140 mm x 189 mm posts in double post configurations, the horizontal clearance between the posts is minimum 2.1 m (measured inside face to inside face of each post).~~

Steel sign support system posts are also designed to fracture near ground level during a passenger vehicle impact. The Nucor Rib-Bak high strength steel post uses a proprietary Lap-Splice and bolts to connect their upper sign post and lower stub post at ground level, with the top of lower stub post set no higher than 100 mm above ground. For double or triple post configurations, they are set no more than 2.1 m apart when measured from outside face of each post as shown in Figure 4-45.

The Sqr-Lok perforated square tube small sign support system uses a 57 mm x 57 mm x 1065mm long lower anchor steel post with top set no higher than 100mm above ground. A 63 mm x 63 mm x 450 mm long sleeve is placed over the stub post with top also set no higher than 100 mm above ground. The 52 mm x 52 mm upper post is inserted to a depth of 200 mm inside of the lower anchor posts and sleeve, and then bolted together with the proprietary corner bolt. For double post configurations they are set no more than 2.1 m apart when measured from outside face of each post as shown in Figure 4-45.

All steel support systems are pre-punched with 11mm diameter holes at 50mm centres for mounting of the signs. These holes can also used to jack out existing lower posts during repairs or relocations.

Design Guidance:

Small sign assemblies consist of one or more signs and tabs mounted on a sign support system with specified sign hardware having a total sign or sign board area not greater than 3.6m^2.These signs may be metal or plywood, and installers are given the option to select the appropriate metal or wooden breakaway sign support system for each small sign assembly based on the dimensions and area of the sign assembly. The system may consist of a single, double, or triple post configuration.

On low speed urban roadways with barrier type curb and posted speeds less than 70 km/h, small signs of up to 90 cm wide by 90 cm high and total sign area including tabs not greater than 0.56m^2 may continue to be installed on non-breakaway U-flange post system. Breakaway systems may also be installed on low speed urban roadways.

The ministry specifies different types of sign support systems based on the type of sign material, sign dimensions, and total area of the sign including any tabs. Breakaway sign support systems should be used for all new sign installations on high speed and low speed roadways within provincial highway right-of-ways unless located behind an appropriate length of existing barrier. New barriers should not be installed or extended for the sole purpose of protecting a new sign assembly on non-breakaway sign supports.

~~In general all sign installations are intended for installation on traversable roadsides with sideslopes 3H:1V or flatter. Posts should be offset more than 1.5m from bottom of drainage ditches, and when installed behind barrier should be offset beyond the working width of the barrier system. Sign installations should not be installed within the 22m x 6m obstacle clear area beyond guide rail terminal systems.~~

~~Sign installations are intended for installation in competent soils of uniform composition. Site foundation conditions requiring a modification to the design or use of another sign support system include:~~

- ~~Rock cut~~
- ~~Rock fills~~
- ~~Soil is exceptionally soft or loose.~~

~~Small signs can measure up to 2.4m wide and up to 1.5m high, with a maximum area up to 3.6 m^2. For durability, different combinations and sizes of breakaway pressure treated wooden and hot dipped galvanized steel sign support system standards have been developed for various sign sizes typically used on provincial highways. Installers have the option to select the appropriate wooden and/or steel sign support system standard for each sign installation dependent upon sign dimensions and sign area.~~

~~General details and dimensions for Permanent Ground Mounted Small Sign Support Systems with single and double wooden post configurations or with single, double or triple steel post configurations can be found in the applicable standards active in MTO's Contract Preparation System.~~

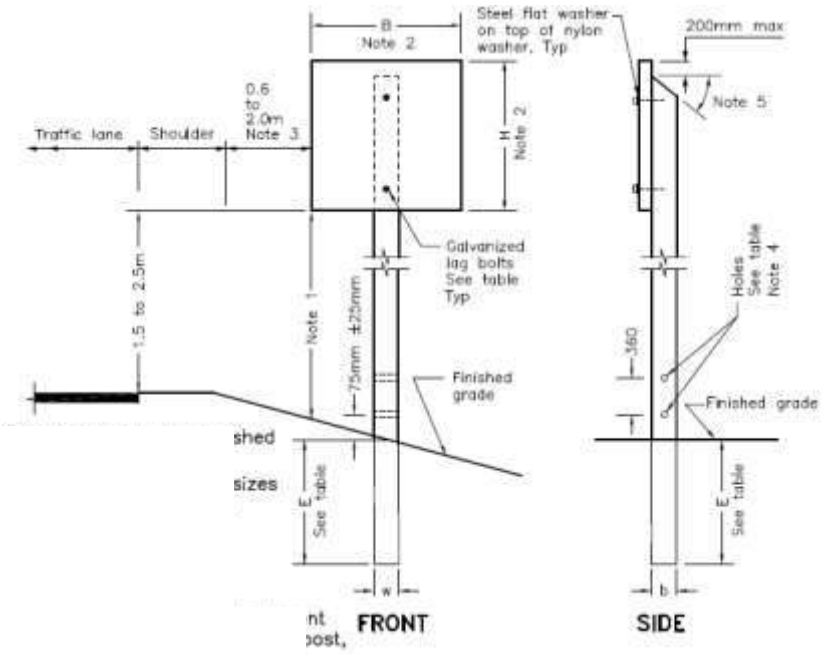
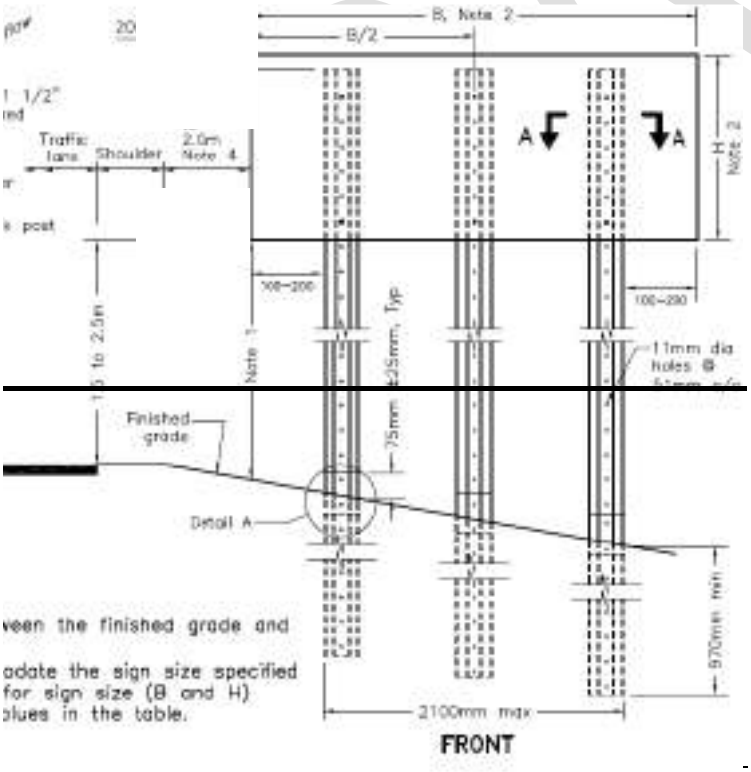


Figure 4-5146: Small Breakaway Single Post System with 89 mm x 140 mm Drilled Wooden Post

See applicable standards for other post configurations and note references



4.5.1.2 Lap-Splice Rib-Bak U-Channel Breakaway System

The Lap-Splice Rib-Bak U-Channel Breakaway System is a proprietary system that meets the crash test acceptance requirements of NCHRP Report 350, Test Level 3. The assembly utilizes two special bolts and a lap-splice spacer to join the upper post and lower post, with the top of the lower stub post set no higher than 100 mm above the fini
minimum depth of 970 mm.

The upper post size is selected to accommodate the sign size
document so that the maximum dimension of the sign size and total area (including tab) does not exceed the values noted in the applicable standards. The system is available in a single, double, or triple post configuration. For multi post configurations, the posts are set no more than 2.1 m apart when measured from the outside face of each post, as illustrated in Figure 4-52~~XX~~.

All posts are pre-punched with 11 mm diameter holes at 51 mm centres or 9.4 mm diameter hole at 25 mm centres to facilitate sign mounting.

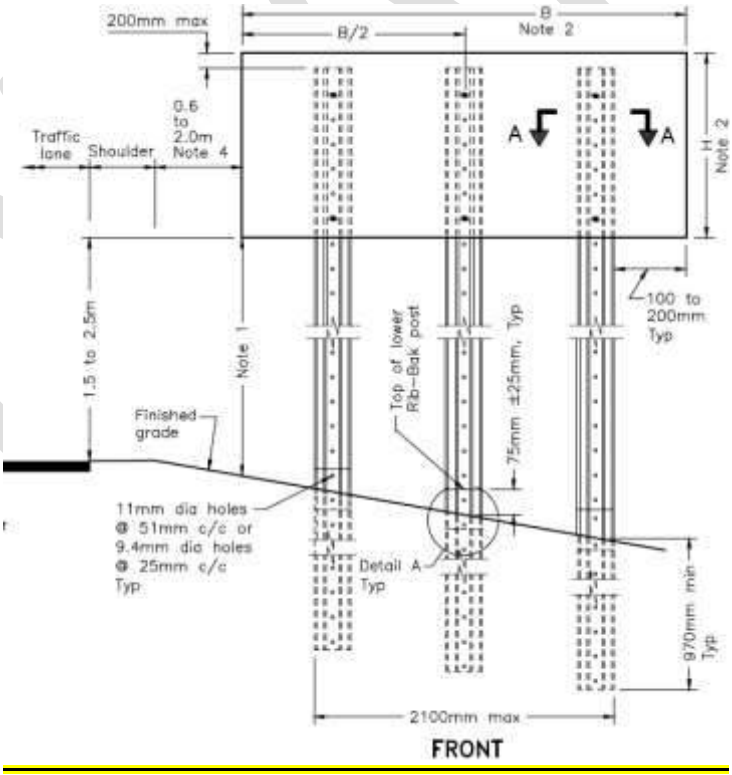


Figure 4-52~~XX47~~: Triple Post Assembly of Lap-Splice Rib-Bak Breakaway System ~~Small Breakaway Triple Post System with Rib-Bak Steel Posts~~

See applicable standards for other post configurations and note references.

4.5.1.3 SQR-LOC Perforated Steel Square Breakaway System

The SQR-LOC Perforated Steel Square Breakaway System is a propriety system that meets the crash test acceptance requirements of MASH, Test Level 3. The assembly utilizes 57 mm x 57 mm x 1065 mm long lower anchor steel post, with top set no higher than 100 mm above ground. A secondary 63 mm x 63 mm x 450 mm long sleeve is positioned over the anchor post, with it's top also set no higher than 100 mm above ground.

The 51 mm x 51 mm upper post is inserted to a depth of 200 mm into the nested lower anchor posts and sleeve assembly, with the components secured via a proprietary corner bolt. The system is available in a single and double post configuration. For double post configurations, the posts are set no more than 2.1 m apart when measured from the outside face of each post, as illustrated in Figure 4-53~~XX~~.

All posts are pre-punched with 11 mm diameter holes at 25.4 mm centres to facilitate sign mounting.

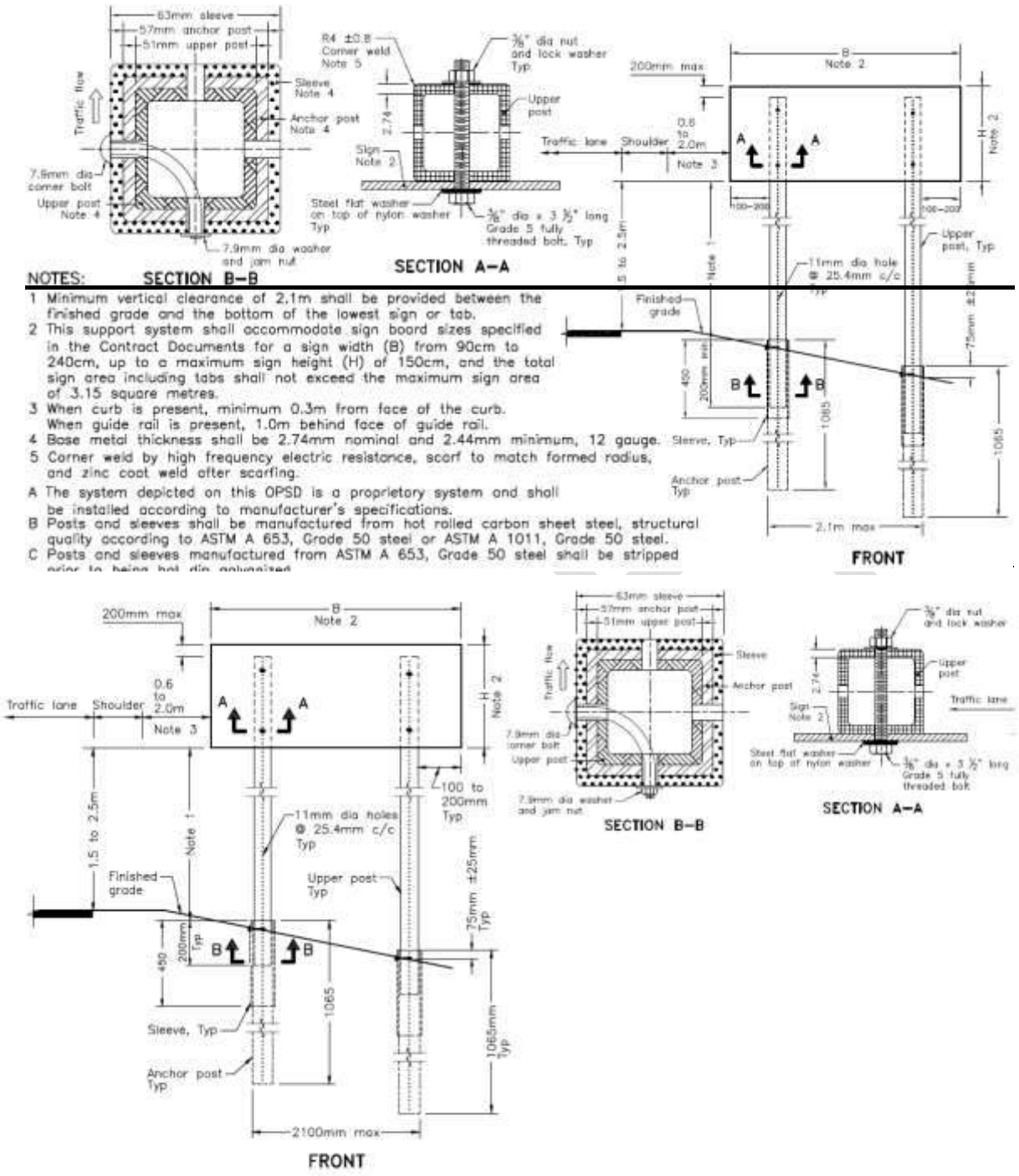


Figure 4-53~~XX~~~~48~~: Double Post Assembly of SQR-LOC Perforated Steel Square Breakaway System ~~Small Breakaway Double Post System with Sqr-Loc Steel Posts~~

See applicable standards for other post configurations and note references.

4.5.1.4 Franklin U-Channel Breakaway System

The Franklin U-Channel Breakaway System is a proprietary system that meets the crash test acceptance requirements of NCHRP Report 350, Test Level 3. The assembly utilizes two special bolts and an unthreaded spacer to join the upper post and lower post, with the top of the lower stub post set no higher than 100 mm above the finished grade and driven to a minimum depth of 965 mm.

The upper post size is selected to accommodate the specific sign dimensions outlined in the contract documents, ensuring that neither the maximum dimension nor the total sign area (inclusive of tabs) exceeds the values established in the applicable standards. The system supports a single, double, or triple post configuration.

In multi-post configurations, the posts are positioned at a maximum distance of 2.1 m apart, measured from the outside face of each post, as illustrated in Figure 4-54~~XX~~. To facilitate universal sign mounting, all posts are pre-punched with 9.51 mm diameter holes at 25 mm centres.

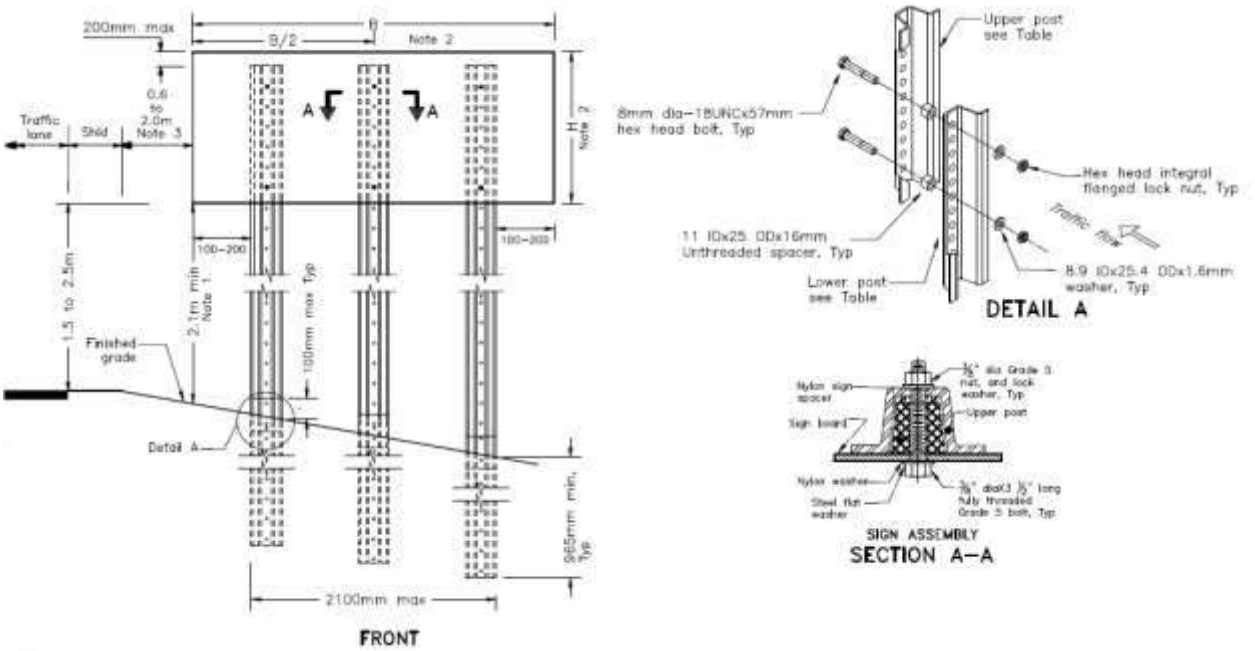


Figure 4-54~~XX~~: Triple Post Assembly of Franklin U-Channel Breakaway System

See applicable standards for other post configurations and note references.

4.5.1.5 Telespar Sign Support Breakaway System

The Telespar Sign Support Breakaway System is a propriety system that meets the crash test acceptance requirements of MASH, Test Level 3. The assembly consist of a 57 mm x 57 mm x 1065 mm long lower anchor steel post with it's top set no higher than 50 mm above ground. A secondary 63 mm x 63 mm x 450 mm long sleeve is placed over the anchor post with it's top also set no higher than 50 mm above ground.

The 51 mm x 51 mm upper post is inserted to a depth of 200 mm into the nested lower anchor posts and sleeve assembly, with the components secured via a proprietary corner bolt. The system is only available in a single post configuration.

All posts are pre-punched with 11 mm diameter holes at 25.4 mm centres to facilitate sign mounting.

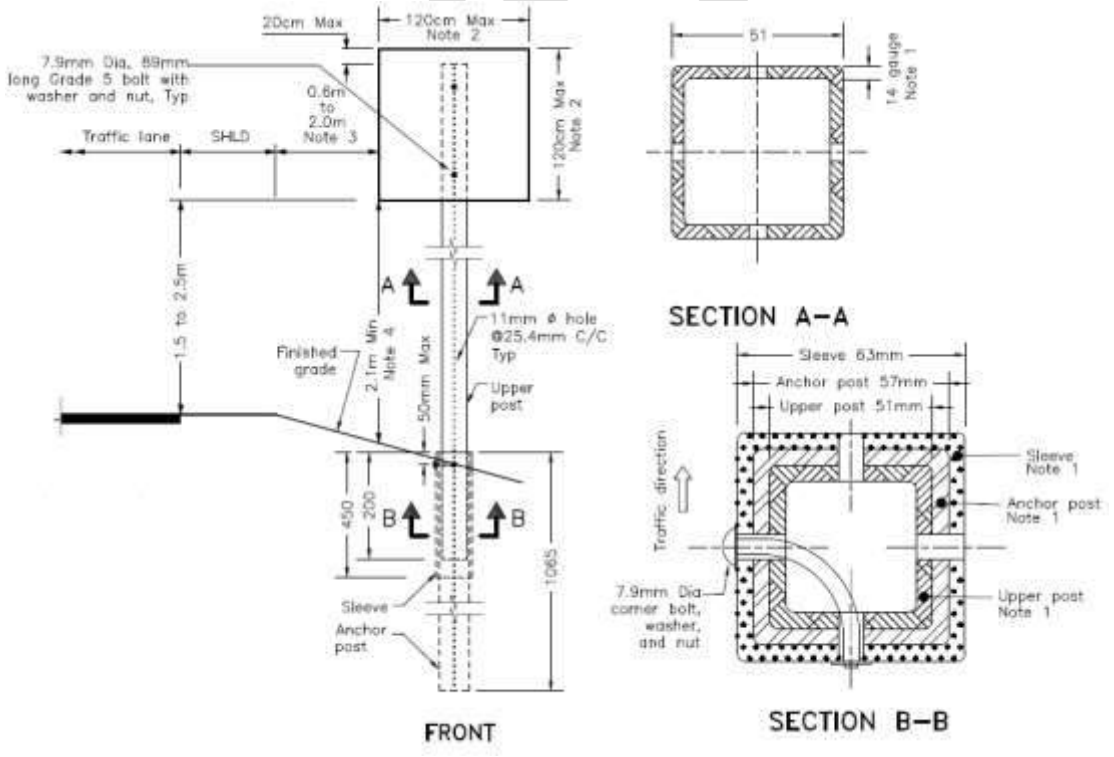


Figure 4-55~~XX~~: Single Post Assembly of Telespar Sign Support Breakaway System

See applicable standards for other post configurations and note references.

4.5.1.6 EcoPoste Collapsible Support Breakaway System

The EcoPoste Collapsible Support Breakaway System is a proprietary system that meets the crash test acceptance requirements of MASH, Test Level 3. The assembly utilizes an 80 mm x 80 mm square tube constructed of recycled high-density polyethylene (HDPE), featuring four internal bores to allow the implementation of reinforcing bars. For structural integrity, the square tube must be installed so that a minimum of 800 mm of its total length remains below grade.

The system is available exclusively in a single post configuration and is designed specifically for use with aluminum composite sign boards. All signs are secured to the square tube via a bracket-type fixation designed to facilitate easy detachment of sign board from signpost in the event of an impact.

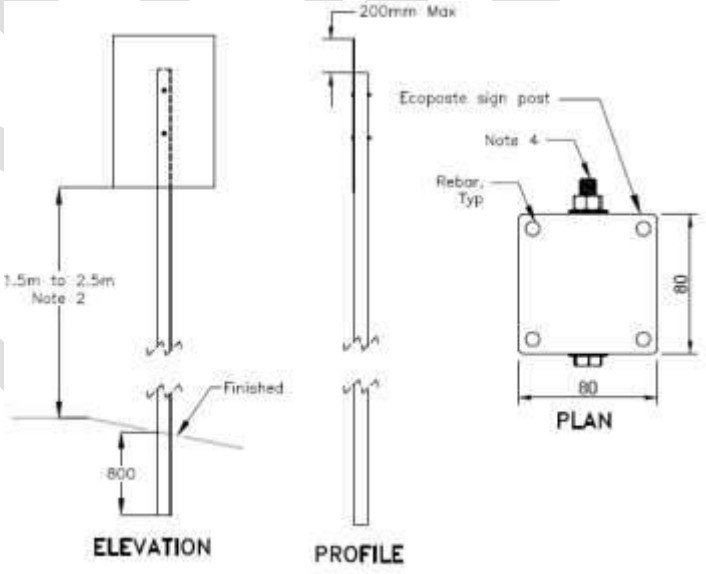


Figure 4-56~~XX~~: Single Post Assembly of EcoPoste Collapsible Support Breakaway System
See applicable standards for other post configurations and note references.

4.5.1.7 U-Flange Non-Breakaway Sign Support System

The U-Flange Non-Breakaway Sign Support System is a non-proprietary system acceptable for implementation on low-speed roadways with posted speeds less than 70 km/h, provided the location is equipped with a barrier curb. The assembly utilizes two bolts to join the upper post and lower post. The lower post, measuring 1525 mm in total length, must be driven to a depth of 900 mm below the finished grade, leaving a remaining height of 625 mm above the surface, as shown in Figure 4-57~~XX~~.

The system is available exclusively in a single post configuration and utilizes steel posts manufactured from either cold-formed or hot-formed steel designed to resist wind loading and will bend upon impact. Sign dimensions are strictly limited to a maximum width of 90 cm and a maximum height of 90 cm, with the total aggregate area (including tabs) not to exceed 0.56 m².

All posts are pre-punched with 11 mm diameter holes at 51 mm centres to facilitate sign mounting.

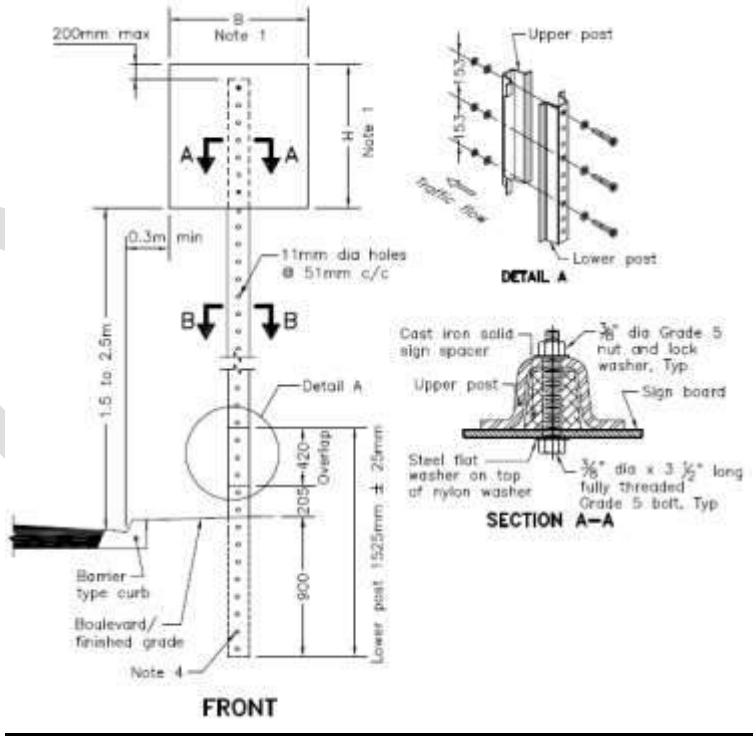


Figure 4-57~~XX~~: Single Post Assembly of U-Flange Non-Breakaway Sign Support System
See applicable standards for other post configurations and note references.

4.5.2 Intermediate Sign Support Systems

Intermediate sign assemblies consist of one or more signs and tabs mounted on a sign support system with specified sign hardware having a width not greater than 2.4 m, a height not greater than 3.0 m, and a total sign or sign board area not greater than 7.2 m^2.

All new permanent intermediate sign support systems installed on capital construction contracts on high-speed provincial highways should be breakaway and meet the crash test acceptance requirements of NCHRP Report 350 TL-3 unless located behind an appropriate length of existing barrier offset appropriately to accommodate barrier working width.

General details and dimensions for permanent ground-mounted Intermediate sign support systems—primarily double steel post configurations—can be found in the applicable standards active in the MTO's Contract Preparation System (CPS).

While 2.4 m wide small signs with heights up to 1.5 m and areas up to 3.6 m² may be installed on intermediate sign support system, it is generally more economical to install small signs on a small sign support system.

Sign installations are intended for installation on traversable roadsides with sideslopes 3H:1V or flatter, and posts should be offset more than 1.5 m from bottom of drainage ditches, and offset more than 2.1 m from the traffic face of a guide rail system.- Design cross-sections shall ensure these minimum offsets are provided.

Sign installations should not be installed within the 22 m × 6 m obstacle clear area behind guide rail terminal systems.

Sign installations are intended for installation in competent soils of uniform composition.- Site foundation conditions requiring a modification to the design or use of another sign support system include:

- Rock cut;
- Rock fills; and
- Soil is exceptionally soft or loose.

4.5.2.1 Slip-Safe Supreme Rib-Bak Breakaway System

The Slip-Safe Supreme Rib-Bak Breakaway System is a proprietary system that meets the crash test acceptance requirements of NCHRP Report 350, Test Level 3. The assembly utilizes upper and lower post sections composed of opposing U-channel posts bolted together, with both sections integrated into specifically designed set of castings. These castings are bolted to one another, and the lower post is driven directly into the ground without the requirement of a concrete footing.

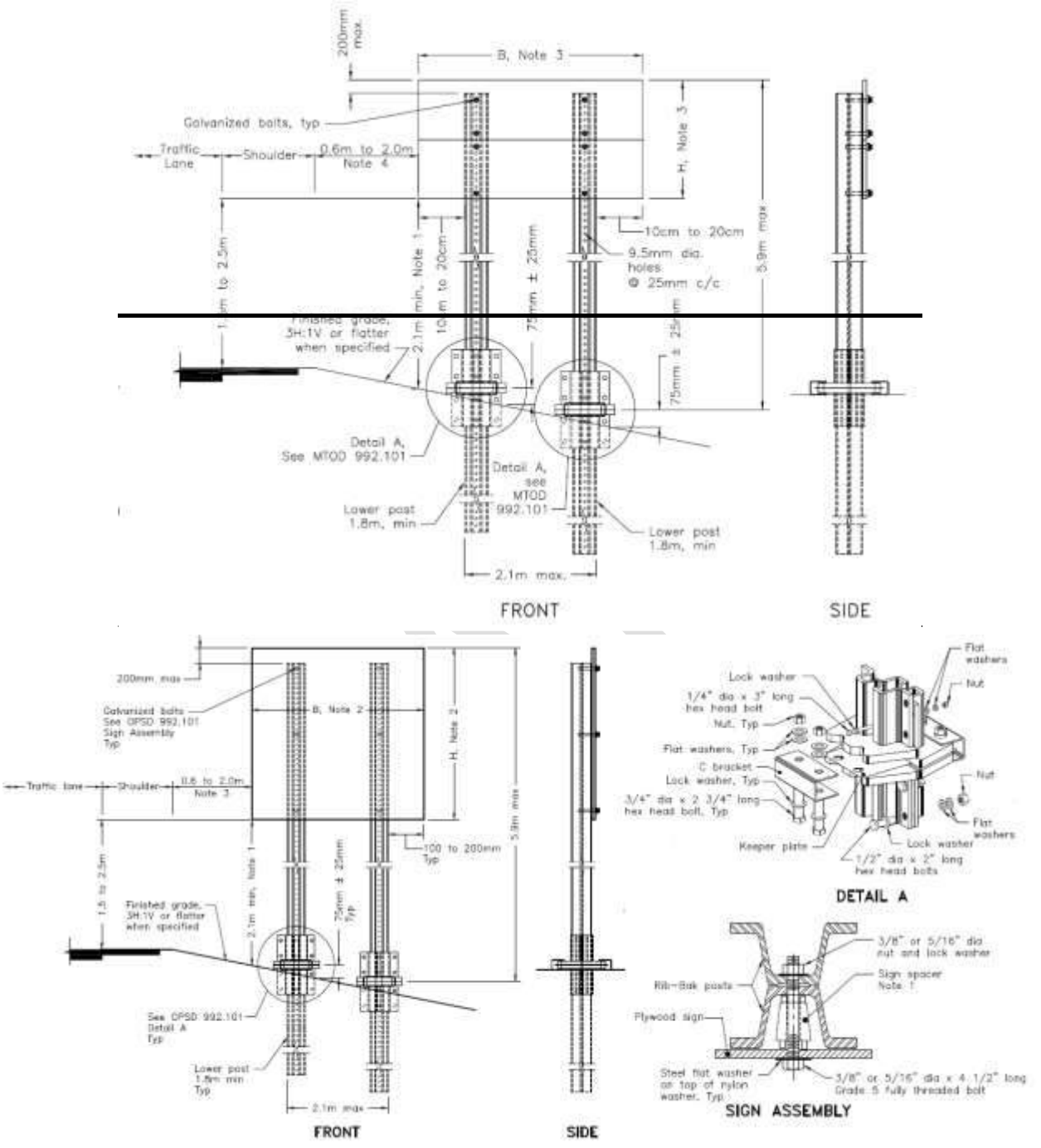
The system is available exclusively in a double post configuration and is designed to accommodate multi-panel plywood sign assemblies with a maximum width of 2.4 m and heights ranging from 1.5 m to 3.0 m, provided the total sign area (including all tabs) remains between 3.6 m² and 7.2 m². While small signs with widths of 2.4 m, heights under 1.5 m, and areas below 3.6 m² may be installed on this intermediate sign support system, it is generally more economical to utilize a small sign support system for these applications. Aluminum extruded signs shall not be installed on the Slip-Safe Supreme system.

For standard installation, the posts are set no more than 2.1 m apart when measured from the outside face of each post, as illustrated in Figure 4-58~~XX~~. All posts are pre-punched with 9.5 mm diameter hole at 25 mm centres to facilitate sign mounting. ~~Intermediate sign assemblies consist of one or more signs and tabs mounted on a sign support system with specified sign hardware having a width not greater than 2.4 m, a height not greater than 3.0 m, and a total sign or sign board area not greater than 7.2 m². These plywood signs are installed on the two-post steel breakaway Slip-Safe Supreme system from Nucor Steel Marion, Inc. and do not require concrete footings. The Slip-Safe Supreme system can be installed and repaired quickly, easily and cost effectively as design and placement of concrete footings are not required.~~

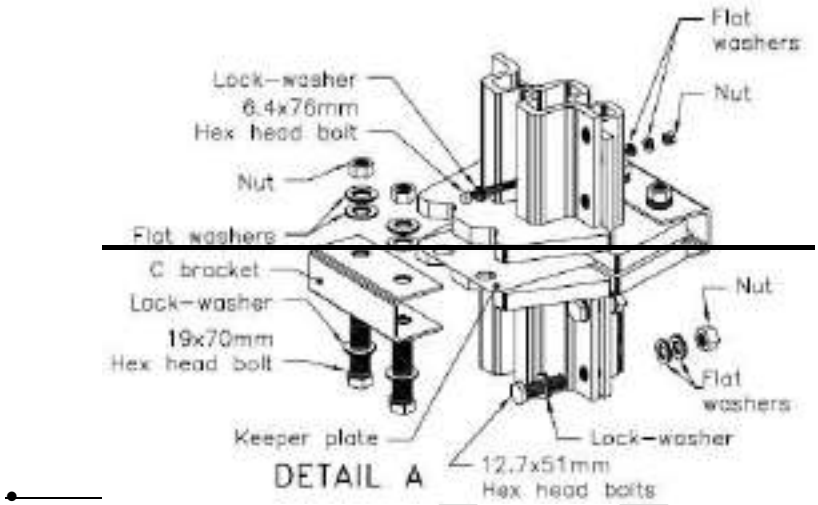
~~The Slip-Safe Supreme™ is a propriety system developed by Nucor Marion Steel, Inc. This system meets the crash test acceptance requirements of NCHRP Report 350, Test Level 3. This is an alternative option for a multi-panel (in height) plywood signs of up to 3.0 m high and up to 2.4 m wide with a maximum area of 7.2 m². It is acceptable to install small 2.4 m wide wood sign assemblies with areas less than 3.6 m² on intermediate sign support systems when specified. At this time, aluminum extruded signs shall not be installed on the Slip-Safe Supreme system.~~

~~The Slip-Safe Supreme system provides a solution for taller plywood signs of up to 3.0 m high and up to 2.4 m wide with a maximum area of 7.2 m². While 2.4 m wide small signs with heights less than 1.5 m and areas less than 3.6m² may be installed on intermediate sign support system, it is generally more economical to install small signs on a small sign support system.~~

~~Figure 4-49: SlipSafe Supreme Intermediate Sign Support System Installation~~


200mm max.
B, Note 3
Galvanized bolts, typ
Traffic Lane
Shoulder
0.6m to 2.0m Note 4
H, Note 3
5.9m max
10cm to 20cm
9.5mm dia. holes @ 25mm c/c
1.5m to 2.5m
2.1m min, Note 1
10cm to 20cm
75mm ± 25mm
Finished grade, 3H:1V or flatter when specified
Detail A, See MTOD 992.101
Detail A, see MTOD 992.101
Lower post 1.8m, min
Lower post 1.8m, min
2.1m max.
FRONT
SIDE
200mm max
Galvanized bolts See OPSD 992.101 Sign Assembly Typ
B, Note 2
H, Note 2
5.9m max
Traffic lane
Shoulder
0.6 to 2.0m Note 3
100 to 200mm Typ
1.5 to 2.5m
2.1m min, Note 1
25mm ± 25mm Typ
Finished grade, 3H:1V or flatter when specified
See OPSD 992.101 Detail A Typ
Lower post 1.8m min Typ
2.1m max
FRONT
SIDE
Flat washers
Lock washer
Nut
1/4" dia x 3" long hex head bolt
Nut, Typ
Flat washers, Typ
C bracket
Lock washer, Typ
3/4" dia x 2 3/4" long hex head bolt, Typ
Nut
Flat washers
Keeper plate
Lock washer
1/2" dia x 2" long hex head bolts
DETAIL A
3/8" or 5/16" dia nut and lock washer
Sign spacer Note 1
Rib-Bak posts
Plywood sign
Steel flat washer or top of nylon washer, Typ
3/8" or 5/16" dia x 4 1/2" long Grade 5 fully threaded bolt
SIGN ASSEMBLY

F



igure 4-58~~XX~~: Double Post Assembly of Slip-Safe Supreme Rib-Bak Breakaway System

See applicable standards for other post configurations and note references.

~~Figure 4-50: Breakaway Component Details~~

~~See applicable standard for other details and note references~~

4.5.2.2 Highway Gator Sign Support Breakaway System

The Highway Gator Sign Support Breakaway System is a proprietary system that meets the crash test acceptance requirements of MASH, Test Level 3. The assembly utilizes 102 mm square steel posts integrated with a triangular slip base assembly and a Unibase Anchor Stub. Installation requires the anchor stub to be secured within a concrete footing in an augured hole, with an anchor stub length of 950 mm and 1220 mm for Southern Ontario and Northern Ontario respectively.

The system is available exclusively in a double post configuration and is designed to accommodate aluminum extruded signs with a maximum width of 4.2 m and heights of 3.0 m, provided the total sign area (i~~ss~~ncluding all tabs) remains below 7.2 m². The aluminum extruded panels are secured to the steel posts through the implementation of stainless-steel sign clamps.

For standard installation, the posts are positioned no more than 2.1 m apart when measured from the centre face of each post. Additionally, the assembly must be configured to ensure a maximum sign overhang of 0.75 m from the post centerline, as illustrated in Figure 4-59~~XX~~.

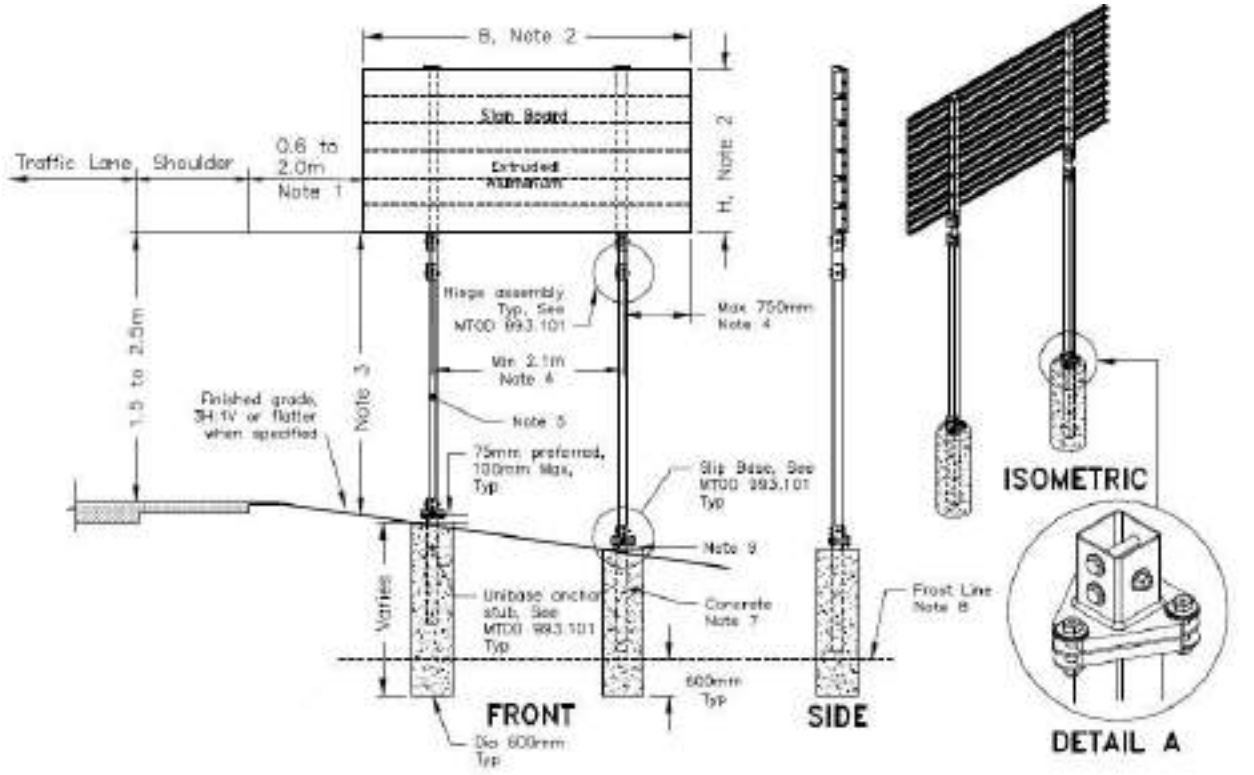


Figure 4-59~~XX~~: Double Post Assembly of Highway Gator Sign Support Breakaway System

See applicable standards for other post configurations and note references.

4.5.3 Sign Supports on Concrete Median Barrier

The sliding base and chute median sign support is a non-propriety system developed by Texas Transportation ~~Institution~~Institution for the Texas Department of Transportation. This system meets the crash test acceptance requirements of MASH Test Level 3. ~~The system consists of a slide assembly which is anchored to the top of the concrete barrier. s~~A collar is placed in the slide assembly which supports a pipe to which the sign board is attached. When impacted by a vehicle from either direction the collar and sign support assembly slides towards the end of the

chute where it is stopped by the anchors. The sign support deforms but does not break away and allows for safe containment and redirection of the vehicle.

This design may be used for signs between 60 and 90 cm wide by 150 cm high and not exceeding 1.35 m^2 in total area. The sliding chute base requires a minimum barrier top width of 200 mm. There is not currently any crash tested designs available for barriers with less than 200 mm top width however a non-tested wooden post with steel plate system is available for use on flared concrete median barriers with a minimum top width of 1.0 m.

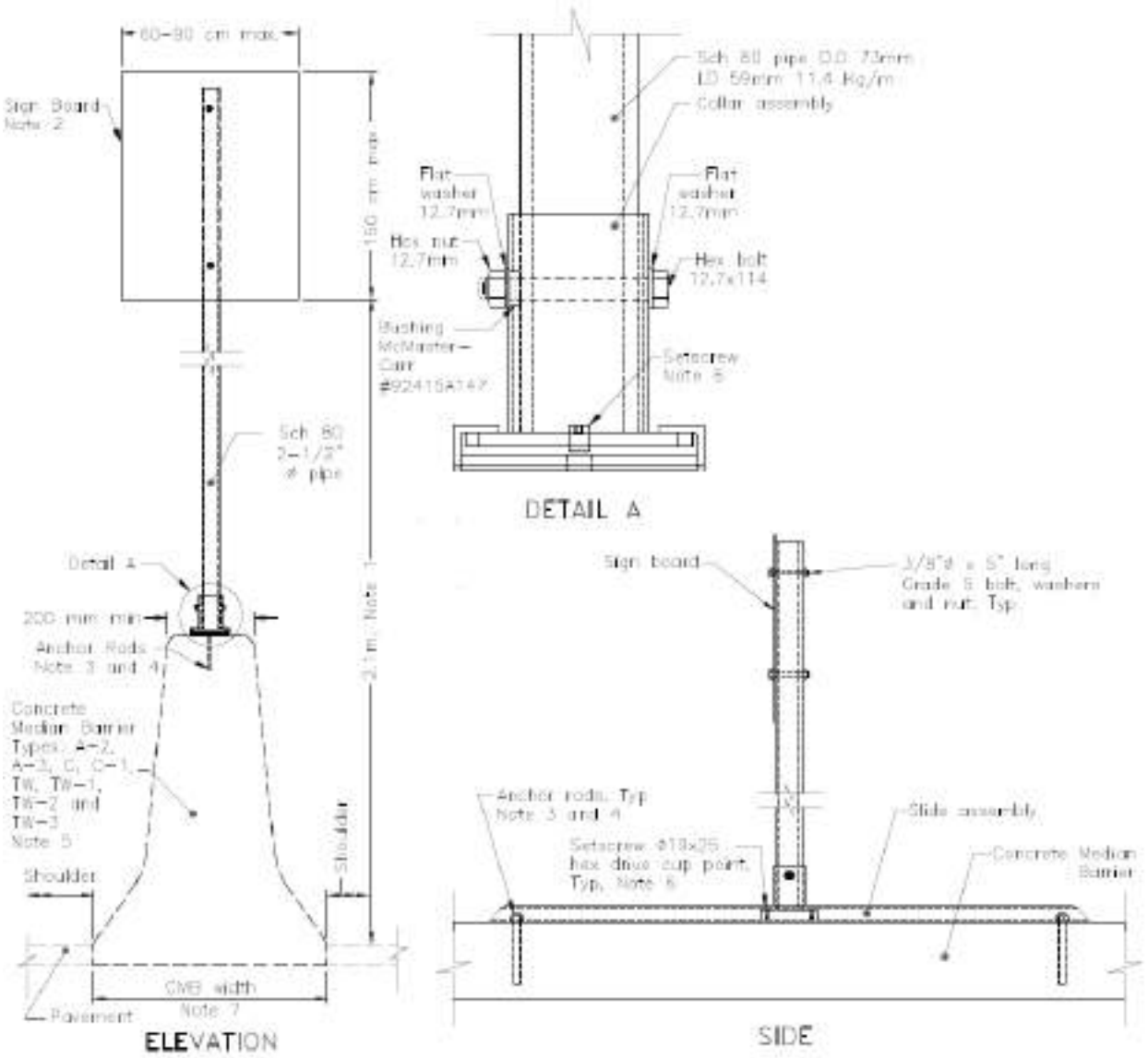
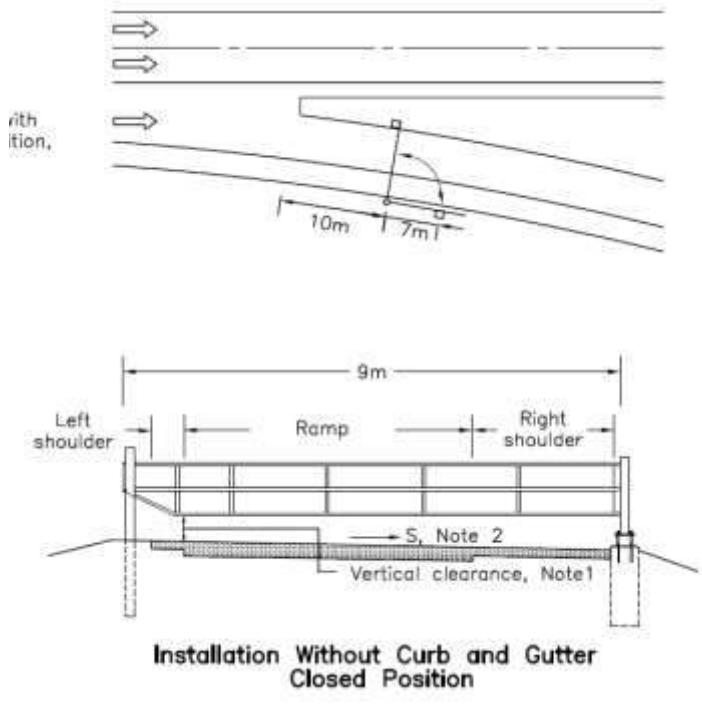


Figure 4-~~60XX51~~: Sliding Base and Chute Median Sign Support System Installation

4.6 Ramp Closure Gates

Since about 2009, most new ramp closure gates installed on provincial highway capital construction contracts should have been breakaway when stored in the ramp open position (gate parallel to traffic). The breakaway ramp closure gate implemented by MTO is considered equivalent to the South Dakota DOT gate that was developed and crash tested by MwRSF in 1995 to meet the crash test acceptance requirements of NCHRP Report 350 TL-3. The gates are manufactured from 50 mm x 50 mm square aluminium tubing and are available in standard 9 m and 12 m lengths. Proprietary breakaway double neck Transpo Pole-Safe couplers are used to attach~~e~~ the aluminium gate to the concrete footing. Gates should be installed adjacent to the right shoulder on the ramp as specified on the MTO standards. Ideally gates should be installed away from roadside barriers however this is not always avoidable. Where gates are installed adjacent to barriers, they should be installed on the traffic side of the barrier. Figure 4-61~~50~~ shows the standard installation for a single lane 9 m entrance ramp from an arterial road to a freeway. Standard sign layouts are available for attachment of required signs to the gate and support post. Designers should select the appropriate gate length and configuration based on the site conditions to ensure that the ramp closure gate(s) will span the roadway when in the closed position.



Installation Without Curb and Gutter Closed Position

Figure 4-61~~52~~: Breakaway Ramp Closure Gate Installed on Ramp Without Curb. Gate shown in ramp closed position.

4.7 Culvert Ends

Exposed crossing culvert ends projecting beyond foreslopes within the desirable clear zone along roadways are considered to be obstacles with high severity indices. Figure ~~Figure~~ 4-62~~51~~ shows an exposed culvert end. Errant vehicles encroaching onto recoverable slopes and non-recoverable slopes can come to abrupt stops or rollover when encountering exposed crossing culvert ends or parallel culvert ends. Various grading design and safety end treatment alternatives are available to minimize probability of impacts by locating culvert ends beyond the desirable clear zone or modifying ends to make them traversable. These options should be considered and evaluated early during hydraulic design of culverts prior to finalizing the length of new culverts and culvert extensions to determine if alternative grading options and safety end treatments can result in a cost beneficial design without having to specify a barrier system to shield the culvert end. Traversable end treatments may also be used on sewer outlets located within the clear zone as applicable.

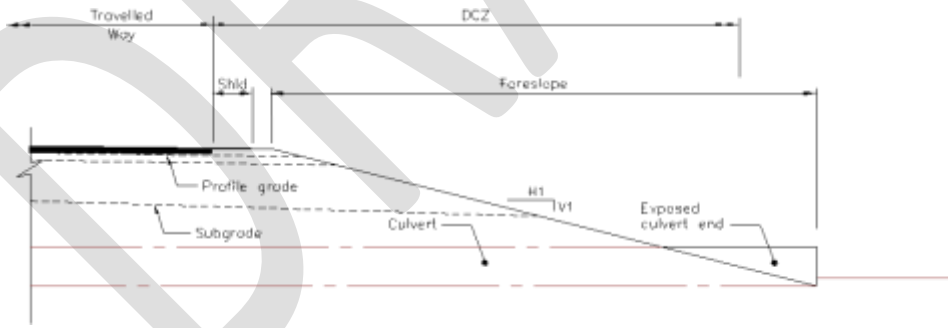


Figure 4-62~~53~~: Exposed Culvert End within Desirable Clear Zone

Steel safety slope end treatments that match 4H:1V and 6H:1V foreslopes as shown in Figure 4-63~~52~~ are available for round culverts ranging in size from 300 mm to 1400 mm diameters, arched pipes up to 2130 mm spans with 1400 mm rise, and elliptical pipes up to 1930 mm spans with 1220 mm rise. For cross culverts with openings wider than 750 mm, longitudinal safety

bars should be used. For parallel culverts, transverse bars should be used. Heavier longitudinal bars are used for concrete box culverts.

Another option is to use a headwall beyond the desirable clear zone and adjust the foreslope as shown in Figure 4-6453. While this option results in a vertical drop off over top of the culvert and headwall, the safety benefits of the increased offset to the headwall versus an exposed end versus a relatively long barrier system in proximity to roadway needs to be analysed as part of a benefit cost evaluation.

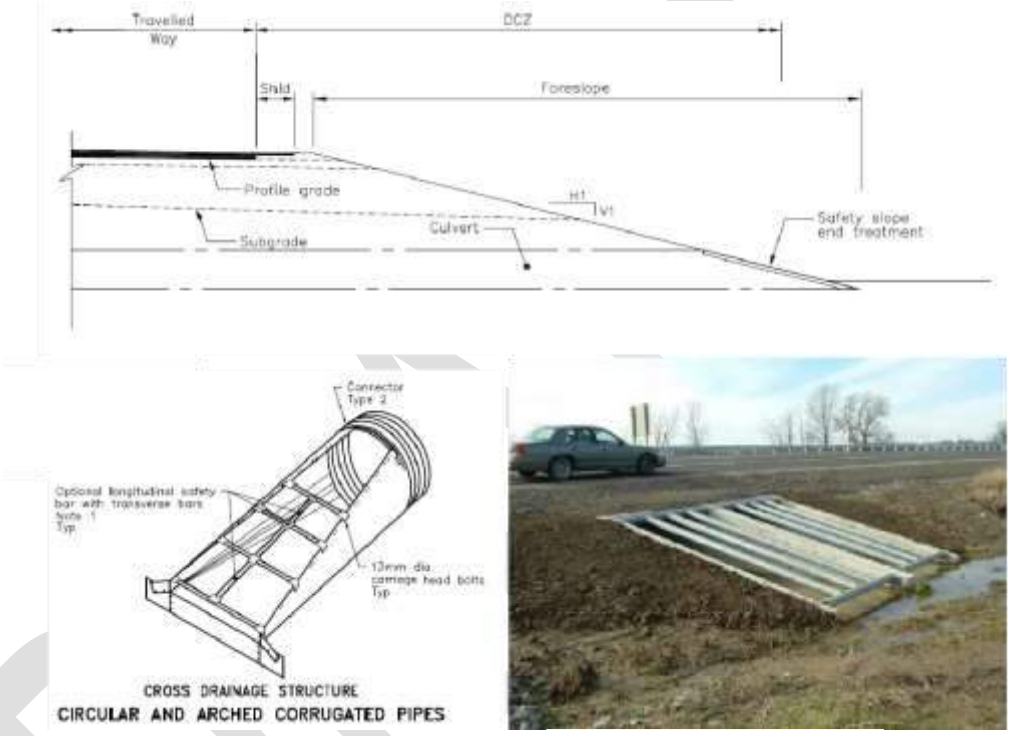


Figure 4-6354: Culvert End with Safety Slope End Treatment

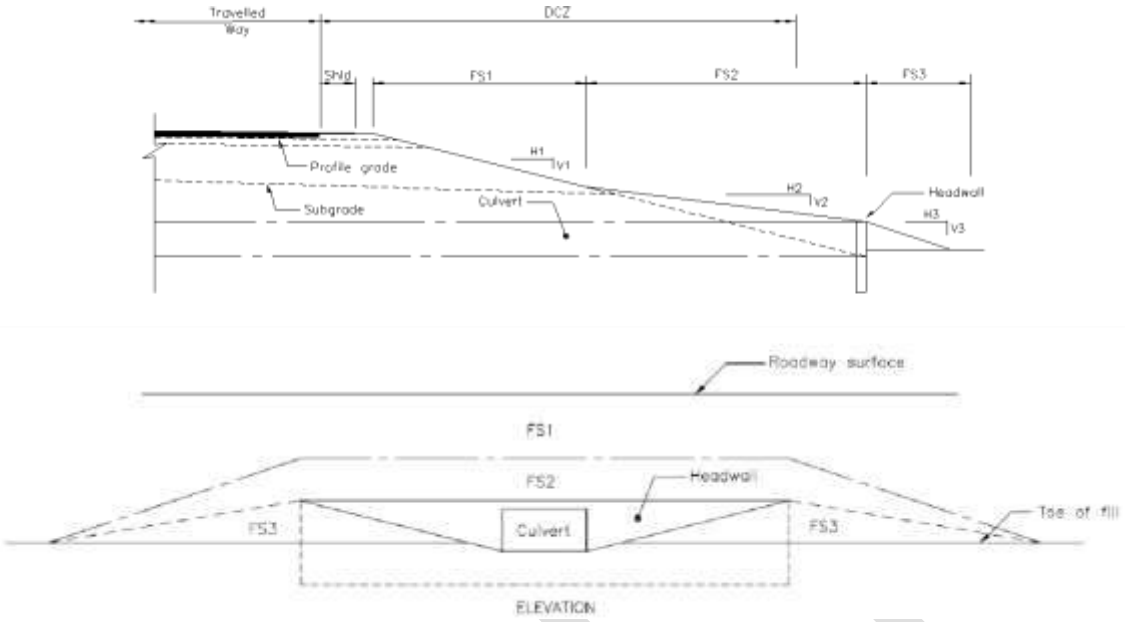


Figure 4-~~64~~55: Culvert End with Headwall