Minimum Length of Barriers

SBTA 21-002

Preamble

To perform satisfactorily, safety barriers must have sufficient length to enable vehicle redirection. In addition, barrier terminals require sufficient support to perform (e.g. absorb energy) as designed and tested.

This technical advice note provides guidance on two periodic questions: ”Is there a minimum length of guardrail that is required to ensure that the system adequately contains and redirects an impacting vehicle?” and “What should be done if the required design length of barrier cannot be installed?” This technical advice addresses TL-3 W-beam barriers; public domain and proprietary systems, and TL-3 wire rope barrier systems. It also provides minimum barrier lengths when these barriers are used on roads where impact speeds of 70 km/h are expected.

Audience

- Road agencies
- Road designers.

Background

When crash testing a barrier, the Manual for Assessing Safety Hardware (MASH) (AASHTO, 2016) requires the minimum article length to be at least three times the length in which deformation is predicted, but not less than 30 m for steel beam systems and 180 m for wire rope safety barriers (WRSBs). The primary basis for testing barriers at these lengths is to accurately predict the working width and dynamic deflection for the barrier system at a location where end (terminal) effects are eliminated.

For shorter systems, a larger portion of a barrier’s redirective force must be carried by the end anchors. Higher anchor loads produce larger longitudinal anchor movements. In general, terminal testing has shown that increases in the longitudinal movement of the anchor can lead to increases in lateral barrier deflection. It is important to understand how shortening a system affects anchor movement, barrier deflection and the ability of the system to redirect vehicles without gating. These qualities will assist in determining appropriate minimum lengths for a barrier system to operate satisfactorily.

Key Performance Characteristics

Every safety barrier system has a crashworthy leading terminal, a section of longitudinal barrier, and a trailing terminal, which may also be crashworthy. To provide an effective minimum barrier length, the following performance characteristics must be considered.

Terminal Performance

Terminals are often crash tested with an attached length of longitudinal barrier. This barrier provides support to the terminal during an impact and is therefore considered part of a system.

Shorter barrier lengths must provide adequate support and anchorage for the terminal to function.

Longitudinal Barrier Performance

For longitudinal barriers, the containment level and working width for a specific product depend on the length that was tested and the support provided upstream and downstream of the impact point. This support includes both the leading and trailing terminals and their anchorage systems.

Shorter barrier lengths may affect the overall capacity of the barrier (e.g. test level) and increase the working width. Shortening the barrier length also increases the likelihood of errant vehicles interacting with the trailing terminal and the system gating.

Points of Redirection

A safety barrier system is able to redirect a vehicle that impacts between the upstream and downstream points of redirection. Refer to Figure 5.22 and Figure 5.22(a) of *Austroads Guide to Road Design Part 6* and *ASBAP Technical Advice STBA 20-003* for guidance on the downstream point of redirection.

Full-Scale Tests on Short Lengths of W-Beam Barrier

Schmidt et al (2015) described a successful MASH TL3 test on a 22.9 m length of Midwest Guardrail System (MGS) barrier. The damage to the barrier and the vehicle between the standard test length and the results from test MGSMIN-1 is shown in Figure 1. The deflection of the barrier was similar in both cases as was the occupants' impact velocities, ride-down accelerations and barrier contact lengths. See Table 1. Although the differences in performance were small, the authors stated:

The 75-ft (22.9-m) long MGS also had more posts yield in the impact region as compared to the 175-ft (53.3-m) long MGS system, which resulted in a slightly longer contact length.

These tests indicate that barriers shorter than the conventional test length will still operate satisfactorily so long as the terminals do not gate and support the loads on the longitudinal barrier.

Figure 1: Comparison between teste 2214MG-2 and MGSMIN-1

Note: The MGSMIN-1 test (22.9 m long barrier) is in the views above and the views for the 2214MG-2 test (53.3 m long barrier) below.

Source: Schmidt et al (2015)

Table 1: Comparison of test results between MASH 3-11 tests 2214MG-2 and MGSMIN-1

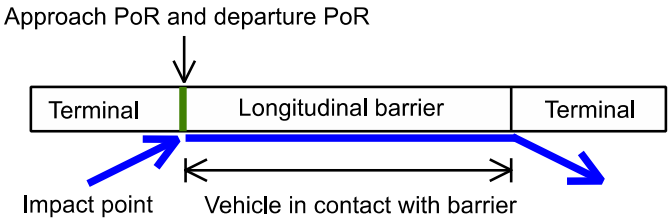
Test Parameter	53.3 m MGS	22.9 m MGS
Test Number	2214MG-2	MGSMIN-1
Vehicle test mass (kg)	2,268	2,248
Impact speed and angle	101 km/h, 25.5°	102 km/h, 24.9°
Longitudinal and lateral OIV (m/s)	4.7, 4.8	4.8, 4.3
Longitudinal and lateral ORA (g)	-8.2, -6.9	-8.1, 5.7
Contact length (m)	10.5	11.3
Dynamic deflection (m)	1.12	1.07

Source: Schmidt et al (2015)

Theoretical Absolute Minimum Barrier Length

The theoretical absolute minimum barrier length is when the approach and departure point of redirection are co-incident. However, a barrier of this length would have minimal application as the barrier would only have a single point where it would redirect a 2270 kg MASH test vehicle. See Figure 2 where it is assumed that the approach point of redirection is at the barrier transition interface. It may be able to redirect smaller vehicles, slower vehicles and those impacting at a smaller angle.

Figure 2: Single point of redirection with an absolute minimum length barrier



Using this concept, the absolute minimum barrier lengths for TL-3 test conditions are:

- 20 m for non-proprietary W-beam systems. This is supported by the simulation results by Schmidt et al (2015).
- 24 m for flexible W-beam systems. The contact lengths for MASH 3-11 tests with flexible W-beam systems are approximately 4 m longer than public domain systems, based on the number of damaged posts.
- 45 m to 52 m for wire rope barriers depending on the particular design. This length includes the terminals.

Installations less than the theoretical absolute minimum length will not redirect a MASH 3-11 test vehicle and would not meet the length of need requirements calculated using the run-out length method. This length establishes the absolute minimum conditions for the barrier to possibly redirect vehicles.

Impacts at 70 km/h into these W-beam systems result in contact lengths being reduced by 3 to 4 m from those for nominally 100 km/h impacts.

The Practical Minimum Barrier Length

While is not possible to be definitive about the practical minimum barrier length, it is assumed that W-beam systems should be two guardrail lengths (8 m) longer than the absolute minimum barrier length.

Using this concept, the practical minimum length of W-beam barriers for TL-3 impacts are:

- 24 m for non-proprietary W-beam systems
- 28 m for flexible W-beam systems.

Using the same approach, the practical minimum length of wire rope barriers should be 50 to 60 m depending on the particular design.

For urban roads where 70 km/h impacts are expected, the practical minimum barrier length can be reduced to:

- 22 m for non-proprietary W-beam systems
- 24 m for flexible W-beam systems.

The Design Minimum Barrier Length

The lengths of need are calculated using the guidance in Part 6 of the *Austroads Guide to Road Design.* The design minimum barrier length is the calculated length of need. In some circumstances, the design minimum length of need can be shorter than the practical minimum length of barrier. In these circumstances, the barrier should be extended to the practical minimum length.

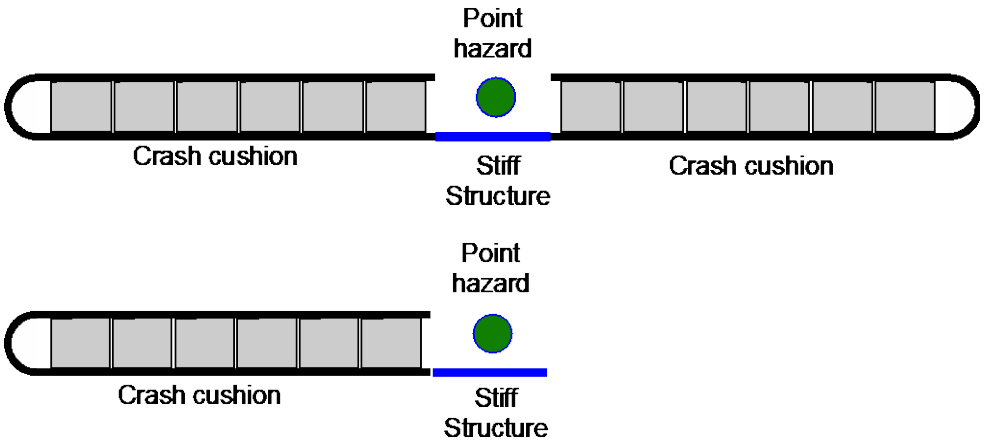
What Should be Done if The Required Design Length of Barrier Cannot be Installed?

A barrier installation should not be shorter than the practical minimum barrier length to provide effective redirection. If it is proposed to install a shorter length of barrier, then the designer should consider this proposal as a design exception and should document the risks and advantages of a shorter installation including alternative barrier designs. The designer should note that a W-beam barrier must not be shorter than the theoretical absolute minimum barrier lengths to enable the barrier to have any ability to redirect vehicles.

Alternative “Barrier” Designs Using Crash Cushions

A redirective crash cushion could be used to shield point hazards. Generally, the crash cushion requires an effective backup structure to support the impact loads. Crash cushions can redirect vehicles impacting on their side. If a stiff structure is used to extend the crash cushion’s coverage then a vehicle will continue to be redirected. A concrete structure or a stiffened steel structure must be able to support the loads in a MASH 3-11 impact. Figure 3 describes this type of installation. The structural integrity and design deflection should be established as part of the engineering design or a design exception. Because the design is stiff, it can be placed reasonably close to a hazard. The system is designed not to gate and when the vehicle leaves the system, and it is free to travel across the verge.

Figure3: Diagrammatic representations of a shielding 'barrier' system for point hazards



Note: The upper configuration is where the system can be impacted from both directions and the lower configuration where impacts are likely from one direction only. A backup structure may be required for the crash cushions.

Commentary

The risk to vehicle occupants is demonstrated through full-scale crash testing and must be within defined thresholds. As such, departure terminals must be crash-tested (using Test 37) to demonstrate acceptable performance during a reverse direction impact by demonstrating that the vehicle does not snag on the terminal and that the occupant injury parameters are within MASH limits. For gating terminals, the vehicle can penetrate the barrier in a controlled fashion.

Design Guidance and Recommendations

An installation of a barrier should be longer than both the practical minimum barrier length and the design minimum barrier length. The practical minimum barrier length was based on crash testing and the absolute theoretical barrier length. The practical minimum length of TL-3 W-beam barriers are:

- 24 m for non-proprietary W-beam systems
- 28 m for flexible W-beam systems.

For urban roads where 70 km/h impacts are expected, the practical minimum barrier length can be reduced to:

- 22 m for non-proprietary W-beam systems
- 24 m for flexible W-beam systems.

The design minimum barrier length is the calculated length of need using the method in *Austroads Guide to Road Design Part 6.*

If a proposed barrier is shorter than the practical minimum barrier length or the design minimum barrier length, then the proposal should be considered to be a design exception and the designer should document the risks and advantages of the installation. The W-beam barrier must not be shorter than the theoretical absolute minimum barrier length; otherwise, the barrier would not have any ability to redirect vehicles.

If a W-beam barrier cannot be installed to meet the design and practical minimum length requirements, then a potential design could consist of redirective crash cushions, arranged as shown in Figure 3, to shield point objects. The structural integrity and design deflection should be investigated as part of the engineering design.

References

Austroads (2022), *Guide to road design part 6: roadside design, safety and barriers*, AGRD06-22, Austroads, Sydney, NSW.

AASHTO (2016), *Manual for assessing safety hardware,* 2nd edn, American Association of State Highway and Transportation Officials, Washington, DC, USA.

Schmidt JD, Weiland NA, Reid JD and Faller RK (2015), Minimum effective length for the Midwest Guardrail System. *Journal of the Transportation Research Board*, Number 2521, pp 67–78. Transportation Research Board, Washington DC.

Amendment Record

Amendment no.	Version no.	Amendment	Date
-	1	New Technical Advice	February 2021
1	2	Measurement corrected – two guardrail lengths (8m)	April 2024