Working Widths for Lower Impact Speeds

SBTA 23-003

Preamble

Permanent and temporary safety barriers are frequently used on roads with an operating speed less than 100 km/h, which is the most common crash tested impact speed.

As such, road designers often query whether a narrower working width may be adopted when space is limited or it is impractical or unfeasible to remove, relocate or modify roadside elements.

In general, a larger barrier-to-hazard distance is safer, as it increases the percentile of vehicles that are shielded from the hazard/worksite. However, larger distances will also limit the space available to provide other roadside objectives.

As such, this Technical Advice provides guidance on:

- How to determine speed-specific working widths.
- When it may be suitable to consider a speed-specific working width.

Please Note: The adoption of a speed-specific working width value may be considered Extended Design Domain or Design Exception by Road Authorities, therefore designers must refer to Road Agency specific standards and guidelines to confirm whether this concept is adopted or will be considered.

Audience

- Road agencies
- Road designers.

Background

American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (MASH) states:

"when selecting test parameters, such as test vehicle, impact speed and angle combination, point of impact, test matrix, etc., every effort is made to specify the worst, or most critical, conditions. For example, the weight of the small car test vehicle was selected to represent approximately the 2nd percentile of passenger vehicles [within the U.S.A], and the impact speed and angle combination represents approximately the 93rd percentile of real-world crashes".

As such, Austroads recommend designing to the crash tested working width value, as this ensures the barrier is equipped to redirect the necessary range of impact scenarios up to the associated test level capacity.

Adopting a narrower working width value should be limited to when the impact conditions are undoubtedly less severe than the testing, and the available space required for other roadside infrastructure is limited.

How to Determine a Speed-Specific Working Width Value

To determine a reasonable speed-specific working width value, the following three methods are recommended.

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All speed-specific working width values should be determined from an equivalent 2270 kg vehicle and an impact angle of 25°. At present, there is insufficient evidence to estimate when other impact angles are suitable, hence impact angles less than 25° are discouraged.

Due to the greater effect of vehicle roll during MASH TL-4 crash tests and higher, these methods are not suitable for taller vehicles that may exhibit roll.

Speed-specific working width values are not reviewed or accepted by the Austroads Safety Barrier Assessment Panel (ASBAP). It is the designer's responsibility to confirm whether a quoted speed-specific working width value has been based on one of these methods.

Speed-Specific Working Widths from Physical Crash Testing

Speed-specific working width values may be determined from physical crash testing using lower impact speeds.

In some cases, product suppliers may have undertaken physical crash testing to determine a working width for lower impact speeds. These values are more accurate than simulation, interpolation and extrapolation. Where physical test values exist, it is critical that the Product Supplier confirms how the working width value has been determined; testing must be based on the MASH protocol and modified for lower speeds.

Speed-Specific Working Widths from Computer Simulation

Speed-specific working width values may be determined using computer simulation that has been validated in accordance with ASBAP Technical Advice SBTA 20-004.

Computer simulation (using a validated model) is considered a reasonable prediction of working width, therefore speed-specific working width values may be based on the impact speed of the simulation.

Speed-Specific Working Widths from Extrapolation

Speed-specific working width values may be determined using an impact energy modification factor.

These values are calculated by extrapolating from an existing crash tested value, such as a MASH TL-3 working width value, using a suitable relationship for lower impact speeds. While this technique is a reasonable estimation of working width, it has the lowest accuracy of all methods, and designers should be conservative in their approach.

Post and Rail Barrier Systems

For wire rope, w-beam and thrie-beam safety barriers, the longitudinal steel rail and cables act in tension during an impact, therefore the deflection of the barrier is considered a linear function of the impact energy and the stiffness (redirecting force) of the barrier. Where the barrier stiffness, the vehicle mass and the impact angle remain the same, we can estimate the dynamic deflection at lower impact speeds using equation 2.

This relationship is used within EN1317.2:2010 to calculate normalized dynamic deflection. Noting that wire rope, w-beam and thrie-beam systems have negligible system width after impact, thus dynamic deflection is equal to working width (refer Figure 1).

$$\text{equation 1: } \frac{m_1(V_1 \sin\alpha_1)^2}{{D_1}^2} = \frac{m_2(V_2 \sin\alpha_2)^2}{{D_2}^2} \;\Big|\; \text{equation 2: } \frac{D_2}{D_1} = \frac{V_2}{V_1}$$

m = vehicle mass, V = velocity/speed, α = impact angle, D = dynamic deflection

Temporary Freestanding Barrier Systems

For temporary freestanding barrier systems, the impacted length of barrier relies on a constant friction and resistance from the pavement surface. Therefore, the deflection of the barrier is considered a function of the impact energy and a constant restraining force. This is represented by equation 3 below.

equation 3: $\frac{m_1(V_1 \sin \alpha_1)^2}{D_1} = \frac{m_2(V_2 \sin \alpha_2)^2}{D_2}$ | equation 4: $D_2 = \frac{D_1\ (V_2 \sin 25°\ )^2}{(V_1 \sin 25°\ )^2}$

m = vehicle mass, V = velocity/speed, α = impact angle, D = dynamic deflection

Where the resistance, the vehicle mass and the impact angle remain constant, the relationship can be used to estimate the deflection of the barrier at lower impact speeds. Refer equation 4. This deflection value is then added to the product system width to obtain a speed-specific working width.

For this relationship, it is recommended that designers adopt a velocity that is 10km/h above the expected operating speed. This caters for inevitable variations in operating speed, pavement conditions and barrier characteristics.

Temporary Pinned/Anchored Barrier Systems

For temporary pinned barrier systems, including systems that are pinned at both ends and/or pinned along the barrier length, the impacted length of barrier relies on some frictional resistance from the pavement and some longitudinal tension from the pins; where the ratio depends on the specific product and the impact location relative to the pins.

As such, the modification factor for temporary pinned barrier systems should be based on equation 2, which is the more conservative relationship.

Summary

Based on these impact energy relationships (equations 1 to 4), Table 1 provides an associated modification factor for lower operating speeds based on extrapolation from a known MASH TL-3 impact scenario.

For example, the extrapolated speed-specific working width for a post and rail barrier in a 70 km/h operating speed environment, would be calculated as x 0.7 of the crash tested MASH TL-3 working width value. In the case of temporary freestanding barriers, the x 0.7 modification factor would be applied to the MASH TL-3 dynamic deflection and then added to the system width.

Table 1: Modification factors for speed-specific working width

Barrier Type	Operating Speed (km/h)						
	100	90	80	70	60	50	40
Post and Rail Systems	-	-	0.8	0.7	0.6	0.5	0.4
Temporary Pinned Systems	-	-	0.8	0.7	0.6	0.5	0.4
Temporary Freestanding Systems	-	-	0.8	0.65	0.5	0.35	0.25

Note: Modification factors based on a 2270 kg vehicle, an impact angle of 25 degrees and an impact speed of 10 km/h more than the posted speed.

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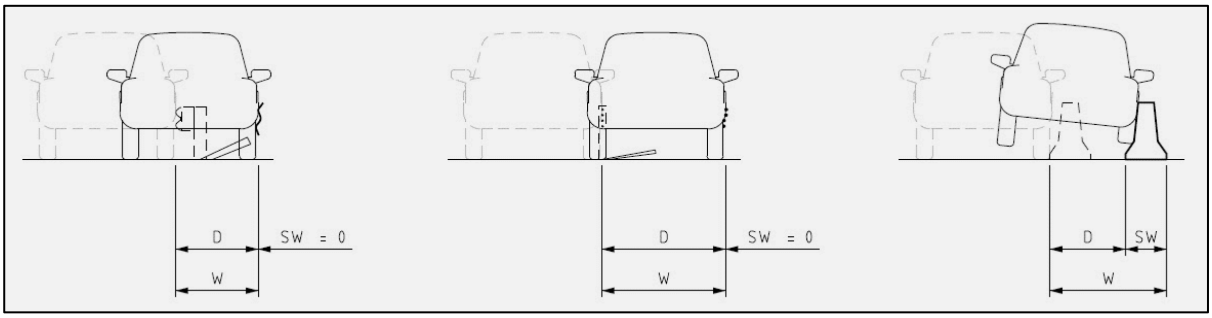
Figure 1: Typical semi-rigid, flexible and temporary barrier performance (TL1-3)



W = Working width, D = Dynamic deflection, R = Roll allowance, SW = System Width

When to Adopt a Speed-Specific Working Width Value

The adoption of a speed-specific working width value may be considered Extended Design Domain or Design Exception by Road Authorities, therefore designers must refer to Road Agency standards and guidelines to confirm whether this concept is adopted or will be considered.

Speed-specific working width values should only be considered when crash tested working width values are impractical and the likelihood of a high-speed impact is justifiably low.

In general, speed-specific working width values should only be considered during design when all of the following conditions are met:

- Where the barrier system is located within an urban environment.
- Where the posted speed is 80km/h or less.
- Where the hazard being protected is not considered high-risk or critical infrastructure.

In addition, it is recommended that the road/location does not have a history of run-off-road crashes. Urban environments have been identified in this case, as the following characteristics are common:

- Roadside space is often limited and must be allocated considering often competing objectives.
- The operating speed is usually less than most barrier crash tests, particularly where vehicles may be stopping frequently.
- Fatigue related run-off-road events are rare therefore, it is common for drivers to brake or attempt to recover before impacting a safety barrier.
- In peak hours, when the exposure for run-off-road and head-on crashed is highest, the operating speed is lower and thus the impact likelihood and severity into safety barriers is lower. In these conditions, barrier impacts are often a secondary outcome from an initial vehicle to vehicle impact.

References

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

EN1317, *European Standard EN 1317 Road Restraint Systems*, European Committee of Standardization, CEN 1998

ASBAP (2020) *ASBAP Technical Advice SBTA 20-004 Assessment of Finite Element Analyses*, Austroads, Sydney. NSW.

Amendment Record

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