

Better than nothing? Safety barriers in construction zones principles and practice

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Abstract

Safety barriers have limited capability to contain and redirect even when installed in a manner that is fully consistent with testing, manufacturer specifications and first principles. Design tolerances for criteria such as impact speed, vehicle type/mass, and impact angles are finite. Crash testing is limited and only covers idealised setup conditions. Such conditions are rarely mimicked in roadwork construction zones for a variety of reasons.

When modified or installed incorrectly, they can fail to protect workers, as well as creating hazards to the public from features such as incorrect end terminals, unconnected longitudinal units, and various improvised configurations.

The author's observations are that minor and significant safety barrier compromises are extremely common in construction zones. This paper shows a sample of common system design/installation issues, discusses design principles and practical installation considerations, and examines how well these are communicated within easily available literature for practitioners.

Background

Temporary safety barriers have evolved rapidly in Australia from around the year 2000. Factors include: the proliferation of proprietary barrier and terminal types; (and hence) the implications of 'reasonably practicable' at law; a changing OHS culture towards 'positive protection'; the formation of Austroads' National Safety Barrier Assessment Panel (ANSBAP); the phasing out of non-tested longitudinal barriers; strict limitations on water-filled end terminals; greater adoption of barriers at building constructors in inner urban / CBD environments; and the desirability of barrier designers/suppliers to meet the newer testing standard of MASH 2009.

In working with small-to-large contractors daily in all road environments, the author rarely observes barrier installations that are consistent with first principles, testing conditions, manufacturer guidelines or road authority guidelines. At times the layouts are the best that can be provided, however, some layouts are so substandard for workers behind them or to the travelling public that the question arises: "are they better than nothing?" (i.e. good delineation/channelisation). As noted in MASH (ASSHTO, 2009), "Seemingly insignificant site conditions such as kerbs, slopes and soft soils can contribute to the unsuccessful performance of a safety feature for some impact conditions".

Aim

Examine safety barrier design principles and practical installation considerations for temporary work zones. Review the type, availability, and quality of relevant guidance material on safety barriers. Comment on issues and gaps in this niche area, and suggest avenues for industry improvement that could lead to safer work sites.

Method

1. List the commonly available safety barrier guidelines, manuals and information sources.
2. Review sources and extract safety barrier first principles and installation guidance / issues.
3. Survey the author's most recent on-site road safety audits (covering a minimum of 20 separate projects and 100 audits) to extract other safety barrier system design / installation issues not covered in the literature review.
4. List and briefly explain the findings, categorised into: 1. first-principles, 2. 'installation design' (Standards Australia, 2015) and, 3. component combinations and other site conditions issues.
5. Provide an indicative quality* rating of how well the safety barrier guidelines and manuals cover first principles and installation issues. *i.e. rigor / length / clarity / ease of use.
6. Provide general commentary on the literature, principle, and practice, and identify specific problems or gaps.
7. Provide comment on possible strategies for improvements.

Scope

Examine first-principles, common scenarios and common guidelines, from the perspective of an average practitioner making decisions on safety barrier layouts. The intent is not to analyse the consequences of particular issues / compromises, or to raise theoretical esoteric unknowns such as: 'what is the threshold quantity of spider cobweb that can be tolerated in WRSB prior to adverse effect on deflection and energy dissipation?'. It is written from the

Australian perspective, with its roots in adopting U.S. test criteria (MASH).



Figure 1. Wildlife nest within wire rope safety barrier

Results (step 1)

Table 1. Commonly available safety barrier guidelines, manuals and information sources.

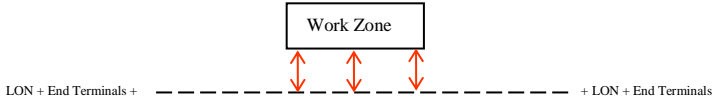

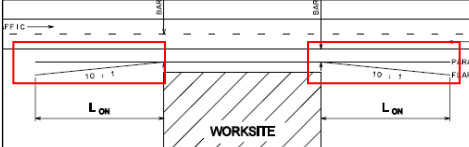




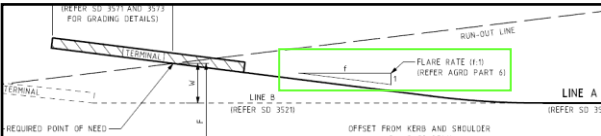


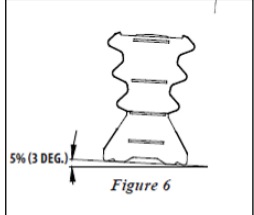

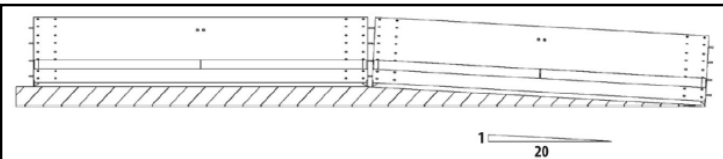
First- Principles and Primary Industry Guides *OA* = Open Access (free)	Secondary or Specialised Industry Guides	Formal and Informal Guidance Specifically Within Roadworks Traffic Management	Other Research and Guidance
MASH (The AASHTO Manual for Assessing Safety Hardware)	Austroads 'Safety Barrier System Conditions' sheets and state-based supplements. *OA*	AS 1742.3 2009. Australian Standard Manual of Uniform Traffic Control Devices. Part 3: Traffic Control for Works on Roads.	Research reports from major research institutions such as TRB (U.K.) and NCHRP (U.S.).
US Department of Transport FHWA (Federal Highway Administration) safety barrier approval letters. *OA*	Austroads Guide to Road Design Part 6: Road Design, Safety and Barriers.	State-based codes of practices / guides for works on roads (e.g. Victoria: Road Management Act 2004 Code of Practice 2004 Worksite Safety - Traffic Management (2010)). *OA*	Research reports from leading state departments of transport such as Texas Transport Institute.
AASHTO Road Design Guide 2011 (4 th Edition)	Road authority supplements to road design guides. *OA*	Road authority issued worksite traffic management fact sheets, hazard reports, newsletters etc. (e.g. Vicroads Worksite Safety Updates). *OA*	Research from specialised road safety institutions such as ARRB, MUARC, and CARRS-Q.
Manufacturer installation guidelines. *OA*	Road authority technical notes/guides on specific barrier classes and particular topics. (e.g. Vicroads Road Design Note 6-08: The Use of Guard Fence). *OA*		Published and unpublished reports and essays from practitioners or companies, and conference proceedings. *OA*
AS/NZS 3845: 2015. Australian / New Zealand Standard Road Safety Barrier Systems and Devices Part 1: Road Safety Barrier Systems.	Road authority standard barrier layout drawings (e.g. Vicroads Standard drawing 3500: Terminology Shorthand and General Requirements for Safety Barriers). *OA*		Specialised training (e.g. IRF SRD2 and SRD3 modules) and non-specialised training (e.g. road safety audit courses).




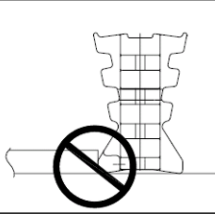







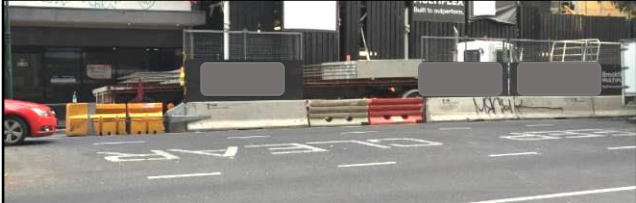
Results (Steps 2-4) – Safety Barrier System Design Principles and Considerations


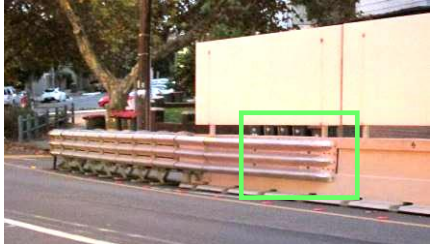
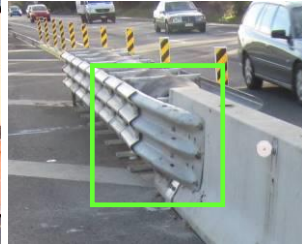









Note: many of the 33 below are related and affect each other but are deliberately deconstructed and isolated to highlight the specific individual principles and considerations at their core. This is not an exhaustive list but attempts to highlight the key principles and considerations.






Table 2. Safety Barrier System Design Principles and Considerations






	Description	Performance implication mainly affecting: <i>workers or public</i>
A. First Principles		
1. Impact speed	Maximum speed the system can be impacted for the design vehicle.	Primarily: Workers Secondary: Public
2. Vehicle mass	Maximum vehicle mass tolerance of the system in accordance with MASH TL categories (i.e. small car, pickup truck, single unit van, trucks).	Workers
 <p>Free-standing single slope barrier Fixed TL-6 ('truck') barrier Transitions between containment levels catering to vehicle mass/height</p>		
3. Impact angle	Maximum angle at which the longitudinal barrier, end terminal or special areas can be struck by an errant vehicle.	Both
 <p>Testing a critical transition point End terminal installed well beyond maximum angles of the system design</p>		
4. Deflection / working width	To workers or excavation / batter-drops.	Workers
 <p>Plant, materials, equipment and facilities within barrier deflection area</p>		
 <p>FIGURE 3.5 PROTECTIVE FENCING BEHIND A SAFETY BARRIER SYSTEM</p> <p>AS1742.3 2009 indicating the requirement for a containment fence</p>  <p>Examples of containment fences</p>		






5. Minimum system length	<p>The length in advance, through, and on departure of the work zone - necessary to provide the deflection along the work zone as per manufacturer guidelines – not including length of need and not including end terminals. Failure to understand this principle can result in total system failure such as barriers tipping over (image below-right). Often numerically equivalent to: manufacturer's test length + work zone length.</p>	<p>Primarily: workers Secondary: public</p>
		 <p>Short run of light barriers tipped over</p>
6. Point of need / length of need	<p>Length of barrier in advance of the work site to shield workers and worksite hazards.</p>	<p>Workers</p>
	 <p> Vicroads Bridge technical Note 2005 / 08 (no longer in use) LON protecting workers from errant vehicle Bunting defining the LON limit </p>	
7. Point of redirection	<p>Point closest to its end at which the barrier is <i>effective</i> by containing and redirecting the test vehicle.</p>	<p>Workers</p>
	 <p> 1. Ironman manual: POC=48m downstream at 70km/h. 2. POC is 20-30m downstream of unpinned barriers behind crash cushion. 3. POC is immediate with pinned barriers </p>	
8. System flare rate	<p>Longitudinal angle to road.</p>	<p>Public</p>
 <p>Example of longitudinal barrier flaring</p>	 <p>Shown schematically in Vicroads Standard Drawing SD3500</p>	
9. Cross slopes	<p>Tolerance of barrier on cross slopes (typically 5%). Can be dependent on whether the cross slope is 'hinged' to the roadway or a constant steep superelevation.</p>	<p>Both</p>
 <p>Barrier with pronounced lean towards work zone with soft surface and inadequate deflection width</p>	  <p>Typical manufacturer guideline (Ironman)</p>	
10. Longitudinal slope / crests / ditches	<p>Tolerance of barrier on longitudinal (constant) slopes, or more sudden crests and ditches. Typically 5%.</p>	<p>Both</p>
 <p>Barrier on a crest due to earth mound</p>	 <p>Example of crest limitation in typical manufacturer guideline (Ironman)</p>	

11. Ground surface	Barriers are tested on hard surfaces where they can slide under low friction, not on soft verges which have the increased potential to affect the lateral movement and rotation of the barrier.	Both
		
Temporary barriers on the edge of a very soft surface	Typical hard surface of test environment.	
12. Kerbs, steps, obstructions	Elements which can affect vehicle stability upon impact, or more severe outcomes such as vaulting, snagging or connection rupture.	Both
		
Barriers and terminal hard up against kerb	Typical manufacturer guideline (Ironman)	Step down behind barriers
		
		High mass object alongside barriers
13. End-terminal run-out area	Area for a safe and snag-free recovery.	Public
		
Rare example of temporary run-out area 'pad'	Example of workers, plant and materials in the terminal runout area.	
B. Installation design		Workers / public
14. Effect on / by other barrier systems in proximity	In isolation a system design might be appropriate, however there are interaction issues with other systems. 'Ultimate' design example provided.	Both
		
Departure-side terminal in the space where the extruding ET2000 rail curls away	ET2000 crash test	
15. Appropriateness of terminal type with barrier type	It is not necessarily the case that every terminal type is suitable for every barrier type. For example, a water-filled terminal attached to barriers restrained to the pavement could lead to excess ride-down forces or exacerbated coffin-corner at the connection point.	Public
16. Transitions between barrier types of differing rigidity	Similar to a guard rail transition to a bridge parapet but utilising temporary safety barriers. Usually a non-approved system resulting from improvisation.	Both
		
Improvised systems transitioning from concrete, to water-filled, back to concrete. Some unconnected.		

17. Directionality of traffic	A system might be appropriate in one traffic direction but not the other.	Public
		
Hazardous exposed rear panels of a crash cushion	Hazard-elimination through utilization of standard product accessory	
18. Offset to traffic lane (shy-line)	Terminals and longitudinal barriers can create a shy-line effect.	Public
		
Barriers and end terminal hard up against traffic	Terminal tapered away from traffic.	
19. Carriageway cross section	Barriers on <i>either</i> side of the road can somewhat affect the cross section and vehicle tracking positions. However, barriers installed on <i>both</i> sides of the road and at higher speed can have greater effects on shy-line and the swept path of vehicles.	Public
		
Bus encroaching into adjacent lane around a corner due to reduced cross section and barriers on both sides with narrow left lane.		
20. Sight distance past barriers and barrier screens	Barriers and their attachments can obscure sight lines.	Public
		
Single slope barriers obscuring sight line to approaching traffic	Barrier screens and site compound fencing obscuring sight line	
21. Barrier screens obstructing visibility to signs.	Barriers and their attachments can obscure sight lines to signs.	Public
		
Variable speed limit sign	Navigational sign	
22. Barrier condition	Leads to a reduced system effectiveness e.g. containment through capture instead of redirection, or, greater deflections, or, total system failure through end terminal failure or pocketing.	Both
		

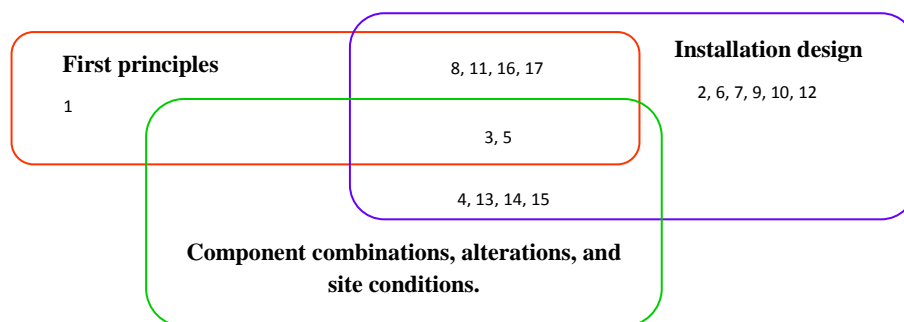
23. Vulnerable road users - pedestrians	Barriers can block natural pedestrian desire-lines, and attachments such as barrier screens can affect sight distance.	Public
 <p>Pedestrians jumping barriers and / or walking along road due to the absence of any realistic alternative</p>		
24. Vulnerable road users - motorcyclists	Protrusions and surface inconsistencies can snag errant vehicles, especially motorcyclists.	Public
 <p>Bolts from (unused) tie-down plates protruding from lower slope of F-shape concrete barrier</p>		
25. Delineation / visibility	Visual notification to drivers of the presence of barriers and shoulder width reduction.	Both
 <p>Tactile edge line, closely-spaced RRPMS, channelisers, diagonal pavement markings</p> <p>Strong edge-line and barrier-mounted RRPMS</p>		
C. Component combinations, alterations, and site conditions.		Workers / public
26. Permanent barrier to temporary barrier: Direct connection	Site conditions / issues may contribute to highly customised non-approved systems that attempt to mimic crash-tested systems. The example below could lead to an increased likelihood of pocketing due to the free-standing barriers.	Both
 <p>Existing guard rail is connected into free-standing temporary barriers with transitional stiffening.</p>		
27. Permanent barrier to existing temporary barrier: No direct connection	A typical scenario will see a temporary barrier without an end terminal tucked behind an existing system. This raises the issue of 'point of redirection'. i.e the temporary barrier only 'contains and redirects' from a set location upstream of its commencement.	Both
 <p>Short overlap introduces a section of unknown effectiveness</p> <p>Overlap correctly taken to a point beyond the 'point of redirection'</p>		

28. Permanent <i>severed</i> barrier overlapping existing barrier: No direct connection	A typical scenario will see a temporary barrier without an end terminal tucked behind an existing system <i>that has been severed</i> and lacks the system-anchorage and tension that an end-terminal normally provides.	Public (mostly)
		
The severed guard rail could lead to excessive deflections resulting in a potentially catastrophic crash outcome from snagging or pocketing.		
29. Layering / overlaps of barriers	A. Laying one barrier type along-side the same barrier-type. In high-speed environments this could increase the risk of vehicle-roll (and barrier vaulting) due to increased pivoting around the base. B. Energy dissipation modes differ dramatically between systems. The combination of two gives rise to potentially significant vehicle stability issues.	Both
		
A. Same barrier type B. Concrete + WRSB = Different barrier type / crash mechanism		
30. Customisation with <i>strong</i> safety barrier engineering and design input	Refer examples below.	Public
		
A. Transitional pinning of free-standing system B. Special transition cap to connect two concrete barrier runs prior to the crash cushion		
31. Customisation / modification <i>without</i> strong safety barrier engineering and design input	Refer examples below.	Both
		
Worker containment rail has hazardous detachable horizontal rails 'Walk-way' on top of barriers Two abutting water-filled terminals		
		
Single water-filled module in front of hazard Gantries supporting offices/sheds connected to barriers Concrete barrier 'end terminal'		

32. Installation and supply mistakes	As well as innocent mistakes, these include <i>deliberate</i> acts such as omitting the reinforcing connector in the Queensland (public domain) single-slope barrier connection.	Both
		
Unconnected barriers due to different connections	Incorrect TL barrier type supplied	Unconnected top-wire Wrong orientation
33. Administrative processes	Workers using barrier and terminals as chairs.	Workers
		

Results (Step 5) – Safety barrier design coverage and quality in guidelines

Figure 2 – Coverage of the three key design areas within guidelines



Quality of coverage (Very Good / Good / Nominal) based on rigor / relevance / clarity / ease of use.

1. MASH: GOOD. Detailed but not written for a work zone barrier installation designer and unlikely to ever be accessed by one.
2. FHA approval letters: NOMINAL. Informative on specific limitations and cautions.
3. ASSHTO RDG 2011: GOOD. Brief coverage of principles. Strong coverage of barrier types and historic development.
4. Manufacturer installation guidelines: VARIABLE. Reviewed: Ironman/JJ-Hooks/Absorb350/BG800. Some 'list' 5-10 key design criteria whereas others explain them in detail.
5. AS/NZS3845.1 2015: GOOD. Excellent broad coverage. Brief coverage of specific topics. Not a practical document for day-to-day use for a work zone barrier installation designer.
6. Road authority standard drawings: e.g. Vicroads SD3501/3500/3502/similar. VERY GOOD. Focus is on *permanent* design.
7. Austroads 'Safety barrier System Conditions' sheets: VERY GOOD. Very practical but solely limited to 'installation design' criteria.
8. Austroads GRD6: VERY GOOD. Excellent broad coverage of the two key criteria types in a practical easy to read format.
9. Road authority supplements to Austroads GRD6: VARIES/ NOMINAL. Clarifies local practices. Expands on some topics.
10. Road authority technical guides: e.g. Vicroads RDN-6-02. VERY GOOD. Robustly expands on particular barriers.
11. AS1742.3 2009: NOMINAL. Brief coverage of small number of key principles.
12. State-based construction traffic management codes of practice: VARIES/ NOMINAL. Clarifies local practices.
13. Road authority issued work site hazard fact sheets: NOMINAL. Discusses one topic in a clear and practical way.
14. Research reports: GOOD. Typically on specific highly technical non-practical installation design topics.
15. Published / unpublished reports and essays from practitioners: GOOD. Typically on specific highly specific and technical installation design topics such as Troutbeck's (2008) technical paper on barriers on top of kerb. Papers covering more general barrier topics and history: VERY GOOD such as work by Grzebieta, Jiang & Carey (2005).
16. Specialised training by IRF: NOMINAL-GOOD. Lengthy / robust training on principles and products.
17. Specialised training in road safety audit courses: NOMINAL. Brief training on principles and products.

Commentary

Whether safety barriers are ‘better than nothing’ really depends on the quality of the system design and installation and is highly site-specific. At times the compromises and risks to workers and the public may outweigh the benefits. Some barrier *installation design* experts ask ‘how do we get them wrong so often?’. Maybe the question should be reframed as ‘how do we ever get them right?’. Research by Gambatese and Johnson (2014) looked into this question. It indicated that quality / consistency / safety of construction zone setups were higher on projects where constructability and design reviews had been conducted and where the project manager and traffic plan designer had more years of experience and had undergone specialised training. This is not surprising, however, it also found that the construction zone designers and construction engineers implementing the setup rated the quality of the setup very differently. The discrepancy between the two perspectives related to how well the original design matched field conditions. In the Australian context this could be critical due to the lack of guidelines covering one particular barrier design criteria in this paper: *3. component combinations, alterations, and site conditions*.

The author’s opinion on the issues and obstacles to improved quality of *system design*:

- *Training*: Lack of dedicated training robustly covering all three design areas at certificate or diploma level.
- *Information availability*: Absence of a consolidated barrier guide or information ‘map’ for a practitioner.
- *Language*: International language differences: e.g. ‘Length of need’ and ‘clear zone’ have different meanings in the U.S. and Australian vernacular.
- *Plans*: Barrier details often lacking on plans (sometimes just a single line on a page).
- *Key principle*: Point of need / length of need is a critical first principle criteria yet it is not well covered within day-to-day installation guidelines.
- *Knowledge*: People acting as ‘system designers’ don’t necessarily have more than a basic knowledge of first principles, testing, energy transfer, barrier failure mechanisms, individual products, product combinations etc.
- *Industry*: Unions / company policies / OHS framework demand ‘positive protection’. This can result in grossly inadequate or outright dangerous barrier setups for workers or the public, i.e. through the perception that any barrier system is ‘better than nothing’.
- *Industry*: Anecdotally, the author hears incorrect design justifications from site engineers such as ‘we’ve done it that way before’ or ‘the site on XYZ Street does it like that’.
- *Practical issues*: Containment fences demarcating the barrier deflection area are rarely implemented.
- *Practical issues*: Existing features such as kerbs cannot be easily removed and the practical availability of clear runoff areas and full lengths-of-need are often rare.
- *Road authority issues*: The project’s speed limit is often defined by the road authority in a contract, i.e. potentially resulting in a mismatch with barrier capabilities, creating work site vulnerabilities.
- *Road authority issues*: The retiring of technical guidelines can throw the baby out with the bath water, e.g. Vicroads’ (retired and redundant) Bridge Technical Note 2005/08 had a highly user-friendly and easy to follow table indicating lengths of need.
- *Note*: Installation sign-offs from suppliers will help with quality of installation, but not necessarily *system design*.

Recommendations

The author’s opinion on the most powerful potential methods of improving the quality of *system design* and therefore worker and public safety:

- Certificate-level or above training for certification in *safety barrier system installation design* covering the three broad criteria areas raised in this paper.
- A review process requiring the desktop and on-site review by a *system installation designer*.
- The availability of a single consolidated and rigorous guide on barriers covering the three broad criteria areas raised in this paper: first principles, installation design, and component combinations, alterations, and site conditions.
- More flexible and progressive road authority attitudes towards low-risk crash-tested elements such as ramped concrete end terminals in low-speed areas.

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