Recommended Higher Performance Bridge Prototype Barriers

Vince Colosimo, B.Eng, G.Dip.CE, G.Dip.ME, MICE.
Manager Bridge Loads – VicRoads Technical Consulting

SYNOPSIS

The implementation of recognizable cost-effective bridge and roadside higher performance level barriers relevant to higher level site risk is essential in order to improve road safety. The traditional low performance barriers of the late 1960’s to the late 1980’s were only designed and in some cases tested to redirect and contain light traffic with mass up to two tonne, such as a heavy car or a three quarter tonne pickup truck.

Most bridge barriers designed and built prior to 1970 do not meet modern requirements for safety. This paper presents results of recent investigations carried out to develop, detail and rationalise prototype barrier systems in accordance with the AS 5100 Design Standard 2004 (4) multiple performance level requirements. The recommended proposed higher performance prototype barriers subject to the approval process in accordance with the AS5100 (4) requirements may in time be accredited and recommended for national use.

The paper builds on and provides detail sizing for barrier prototype systems based on concept arrangements presented in previous papers. The introduction of recognizable national barriers will reduce accident severity at bridges while providing cost effective uniform practices.

Keywords: bridge barriers, parapets, tested, design, prototype, standards, selection, containment, road safety.

ACKNOWLEDGEMENT: The author wishes to thank the Chief Executive of VicRoads Mr. Gary Liddle for his permission to publish this paper. The author wishes to acknowledge the assistance provided by VicRoads Structures support staff including Adi Sarwono and Gary Ravizza for their assistance in providing proof analysis and drafting of barrier modifications. The views expressed in this paper are those of the author and do not necessarily reflect the views of VicRoads.
1. Introduction and Scope

Bridge Barriers have been the subject of ongoing investigations in recent years as emphasis on road safety has intensified. There has also been a major shift in road traffic towards smaller vehicles and heavier commercial trucks. The implementation of cost-effective bridge and roadside barriers relevant to the traffic mix and site risk is thus important for road safety.

The bulk of roadside barriers in existence today are still the low performance light vehicle barriers first introduced in the late 1960’s which can only contain two tonne cars, four wheel drive’s and quarter tonne pickup trucks. The multiple performance barrier level requirements were first introduced in the Austroads 1992 Bridge Code (5). The special high performance level was introduced in a descriptive context and was in practice not adopted on sufficient sites to have any major recognisable statistical effect on road safety.

VicRoads has since October 1997 implemented guidelines for the design and performance selection of appropriate barriers relevant to site risk (refer to references 8 and 9). These have formed the basis of the AS 5100 Standard (4) sections on multiple performance barrier provisions. The Standard provides requirements for multiple performance level selection, design and acceptance of crashworthy barriers.

This paper includes details of tested barrier systems which with minor modifications have formed the basis for the design of recognisable multiple performance level barriers. It presents details of new higher performance barriers with designed minor modifications aimed at optimising performance in line with the requirements of the AS 5100 standard (4) and other evolving test vehicle requirements.

The background investigations for implementation of rational multi-performance level barriers based on benefit cost considerations and site risk where reported in recent years in a number of papers and reports which are included in the list of references to this paper.

The main objective of this paper is to present details of new prototype barriers which subject to appropriate acceptance in line with the AS5100 Standard (4) may lead to future rational recognisable standards.

2. Barrier Performance Levels

The AS5100 Bridge Design (4) provisions are based on rationalisation of international practices including local research analysis and investigations (refer to references listed).

The AS5100 standard specifies a number of barrier performance levels with the associated design, crash testing and selection requirements for each
performance level. For replacement traffic barriers on existing bridges, the authority may determine that a performance level intermediate between the levels nominated may be appropriate, on the basis of a risk assessment.

A Special performance level barriers should be provided, where specified by the Authority, for site specific, unusual conditions at critical locations where it is essential that penetration or vaulting by vehicles specified by the authority (and the AS 5100 standard (4)) under various impact conditions needs to be prevented.

The following summarised extracts from the AS 5100 standard (4) are included to indicate basic details of the multiple performance level criteria.

2.1 Crash Test Vehicles

The vehicles to be safely contained, at specific design speeds and angles of impact, by the different Performance Level barriers shall be those specified as shown in Table 1.

Table 1 - Crash test vehicles and criteria for performance levels

<table>
<thead>
<tr>
<th>Barrier performance level</th>
<th>Vehicles</th>
<th>Test speed Km/h</th>
<th>Impact angle Degrees</th>
<th>TRB-NCHRP Report 350 test level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0.8 t Small car 2.0 t Utility (see Note 1)</td>
<td>70 70</td>
<td>20 25</td>
<td>TL2</td>
</tr>
<tr>
<td>Regular</td>
<td>0.8 t Small car 2.0 t Utility 8 t Rigid truck (see Note 1)</td>
<td>100 100 80</td>
<td>20 25 15</td>
<td>TL4</td>
</tr>
<tr>
<td>Medium</td>
<td>0.8 t Small car 2.0 t Utility 36 t Articulated van (see Note 1)</td>
<td>100 100 80</td>
<td>20 25 15</td>
<td>TL5</td>
</tr>
<tr>
<td>Special e.g. High</td>
<td>To be determined for specific site 0.8 t Small car 2.0 t Utility 44 t Articulated van (see Note 1)</td>
<td>Site specific 100 100 100</td>
<td>Site specific 20 25 15</td>
<td>(see Note 2)</td>
</tr>
</tbody>
</table>

NOTES:
1 Controlling strength test vehicles.
3 No equivalent test level in the Transportation Research Board Report (1993), TRB-NCHRP Report 350. The controlling strength test vehicle may be a 44 t articulated van substituted for or the 36 t tanker.
For other requirements the TRB-NCHRP Report 350, test level 6 shall be used.

2.2 Traffic barrier design loads
The ultimate design loads and test vehicle impact contact lengths for each traffic barrier Performance Level are specified in Table 2.

### Table 2 - Design Loads and Contact Lengths

<table>
<thead>
<tr>
<th>Barrier Performance Level</th>
<th>Ultimate Transverse Outward Load FT kN</th>
<th>Ultimate Longitudinal or Transverse Inward Load FL kN</th>
<th>Vehicle Contact Length for Transverse and Longitudinal Loads LT and LL m</th>
<th>Ultimate Vertical Downward Load FV</th>
<th>Vehicle Contact Length for Vertical Loads LV m</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>125</td>
<td>40</td>
<td>1.1</td>
<td>20</td>
<td>5.5</td>
</tr>
<tr>
<td>REGULAR</td>
<td>250</td>
<td>80</td>
<td>1.1</td>
<td>80</td>
<td>5.5</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>500</td>
<td>170</td>
<td>2.4</td>
<td>220</td>
<td>12</td>
</tr>
<tr>
<td>SPECIAL (High)</td>
<td>1000</td>
<td>330</td>
<td>2.5</td>
<td>380</td>
<td>15</td>
</tr>
</tbody>
</table>

Note: Table data is based on a lateral combined barrier-vehicle deformation (for the respective performance levels) of: 0.3 metre for the Low, 0.4 metre for the Regular, 0.5 metre for the Medium and 0.6 metre for the Special-(High).

### 2.3 Effective Height

The effective height of a barrier is defined as the height of the resultant of the lateral resistance forces of the individual components of the barrier. Traffic barriers should have an effective height greater than or equal to the required minimum effective height specified in Table 3.

### Table 3 Barrier Minimum Effective Heights

<table>
<thead>
<tr>
<th>Barrier Performance Level</th>
<th>Minimum Effective Height mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>500</td>
</tr>
<tr>
<td>REGULAR</td>
<td>800</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>1100</td>
</tr>
<tr>
<td>SPECIAL-High</td>
<td>1400</td>
</tr>
</tbody>
</table>

The methodology for computing the effective height of the barrier is provided in the AASHTO (3) LRFD Bridge Specifications.
3. Tested Barriers

Tested barriers for relevant performance levels are indicated in Figure 1. Recommended minor modifications/improvements are shown in dotted lines. These tested systems with designed minor modifications and improvements in accordance with the AS 5100 (4) standard requirements have formed the basis for the VicRoads barrier designs since 1997.

Examples of barriers designed and used recently will be shown at the presentation of this paper.

4. Basis of Modification Improvements

The basis of modification improvements to the tested barriers has included the following requirements and considerations:
4.1 Member section size and strength:

Barriers modifications were analysed and designed to ensure that the tested behaviour of the barrier would not be compromised but marginally improved while adopting local materials. Component member sizing and geometry was analysed and modified to ensure that the barrier would also comply with the current AS 5100 (4) design requirements. Note that our standard is very closely aligned to the AASHTO LRFD Specification 1994 (2) barrier performance levels and the respective AASHTO LRFD Specification 2007 (3) test vehicle prototype design loads and other essential requirements. An attempt was made to provide rails at appropriate positions as indicated in the AS3845 Road safety barrier systems standard (14). This is to ensure that the rails redirect the test vehicles effectively from the body, wheel and truck floor.

4.2 Barrier Height:

Minor barrier height improvements were made in consideration of the following factors:

- The AASHTO 1989 Specification (1) reported results of impacting test vehicles against a barrier wall to determine load contact areas. It was found that the vehicle impacts the barrier wall and transfers load by making contact from body, wheel, tyres etc. as indicated in Figure (2). In the case of the regular barrier the body wheel contact area depth was 356mm and the applied load was shown centrally positioned in the contact area. This means that for an effective height (or barrier resultant restraint force) of 800 mm the true height should be $800 + 178 = 978$ mm rather than the current 810 mm.

![Figure 2 - Barrier Loading Patterns](image)

\[
h_y = (1.9 - 2.1) + 200
\]
\[
h_y = 1.3 \pm 75
\]
\[
h_{ww} = (406 - 483) + 230
\]

- The effective height formula from the AASHTO Specifications (3) 2007 indicates an effective height requirement of 860mm rather than 800mm for the regular performance barrier. The AS 3845 Road safety barrier systems standard (14) also requires the height of a concrete barrier to be no less
than the effective height plus 50 mm in an attempt to overcome the height deficiency.

- The true height of the barrier should be increased beyond its effective height to allow for its lying down rotation when deflecting under impact. For this purpose, it is recommended that the lateral rotation of a post and rail barrier should be limited to a maximum of 40 degrees under test vehicle impacts, to minimise the potential for vehicle ramping.

- In recent times, tests reported on both the type F safety shape barrier and the single sloped barrier indicate that the vehicle tends to climb beyond the height of the existing barrier height when it is built to the theoretical effective height value. This is understandable and does not necessarily indicate deficiency in the barrier but in its limited height.

- We should also note that the British-European practice is to have relatively basic low performance concrete barriers at no less than one metre height. In addition some USA States have also installed some concrete barriers at heights in excess of the low effective heights required by the LRFD Specifications (3).

- Consideration has also been made to the fact that the new (Draft) (replacement for the NCHRP 350 (12)) AASHTO MASH 08 Manual for Assessment of Safety Hardware (15) when published will marginally increase current test vehicle criteria to require marginally higher barriers. This will increase the regular 8 tonne vehicle to 10 tonne, the 2 tonne pickup truck to 2.27 tonne and the 0.8 tonne to 1.1 tonne with a change in impact angle from 20 to 25 degrees.

This paper includes marginally higher barriers in order to address some if not all of these stated requirements and deficiencies of existing barriers. The marginal increase in height will also address the current concern with the possibility of providing limited future pavement overlays and the barriers can more readily cater for pavement level construction tolerances. For the Type F barrier the vertical lip can be built (subject to Authority approval) to 80 mm ± 15 mm to cater for these practical requirements while maintaining containment capacity for the performance test vehicles.

5. Proposed Standard Barriers

Considerable progress has already been made in developing a recommended range of standard barriers, which can be introduced as interim standards. Proposed standard barrier cross sections for the various Performance Levels are shown in Figure 3.

An attempt has been made to optimise details for these proposals in order to minimise material and costs while maintaining the required performance design loads and vehicle containment capacity.
Figure 3 – Barrier Proposals
6. Structural Details

Specific details including member size and reinforcement are provided and shown in this section as follows:

6.1 Cross Sections

Detailed cross sections are shown in Figures 4, 5 and 6.

Figure 4 - REGULAR (a) Concrete and (b) Combined barrier

Figure 5 - MEDIUM (a) Concrete and (b) Combined barrier
Note that the DIWIDAG 20 mm Diameter reinforcement is extracted from the Italian tested barrier arrangement in Figure 1.

6.2 Precast concrete barrier continuity Plate

Precast barriers near joints will need to be strengthened to cater for the reduced distribution of the design load when applied near the top end of the parapet. This can be done by reducing the spacing of ligatures by the order of 33% near the ends. For example for the regular 3 m concrete parapet units, the N16 ligatures at 150 mm c/s should be increased to N16 at 100mm centres, over one metre length at each end. The recommended alternative is to provide a galvanised steel plate fixed and bolted to the top of the parapet sections respectively, refer to Figure 7.
6.3 Expansion Joints

The AS 5100 standard (4) requires 75% tensile continuity of rails over expansion joints with movement less than or equal to 50mm. Typical details are indicated in Figure 8.

For movements in excess of 50mm the splice joint does not function as well and becomes very costly, therefore a gap can be left between the rail(s) over the joint over the joints. Note that to avoid encroaching vehicles impaling on the exposed rail end a bridging plate or sleeve needs to be provided over the gap refer to Figure 9. In addition consideration should be made to grouting the gap with an approved polymer modified cement grout.
6.4 Transitions

Transition details between the bridge barrier and the approach lower performance barrier should ensure gradual reduction in barrier strength and stiffness while maintaining a smooth traffic face and tensile strength of the weakest joining section. Refer to Figure 10 for details between a two rail barrier and the approach guardrail.

Figure 10 – Transition between a two rail barrier and approach guardrail.
For details between the three rail and the approach guardrail refer to Figure 11.

![Figure 11 - Three rail barrier to guardrail transition](image)

### 8 Conclusions

- Barriers detailed in this paper are presented as an aid to facilitate the introduction and use of uniform rational barriers. This will facilitate the approval and introduction of recognisable standard barriers for multiple performance level criteria suited to the site risk.

- It is proposed that barrier systems detailed in this report may lead to acceptance in accordance with the AS 5100 standard (4). The proposed barrier details with additional improvements resulting from the acceptance process (such as simulation and or prototype testing), may be considered as the basis of future Austroads approved Standards for national use. This will improve road safety.
10 References


9. COLOSIMO V. “Design Requirements for Bridge Traffic Barriers”, VicRoads - Principal Bridge Engineer’s Section, internal Report No 971001, 7 Th. October 1997.

10. COLOSIMO, V. “Selection Guidelines For Bridge Barriers”, ITE International Road Safety & Traffic Engineering Conference, Melbourne 6-7 September 1999.


11 AUTHOR BIOGRAPHY

Vince Colosimo is an Engineer leading the bridge loading Assets Group of the Bridge Section, VicRoads. He joined the organisation in 1966 and has extensive experience in the design of bridges and other road structures. Other experience includes road design and bridge construction. He is currently the Manager Bridge Loads, responsible for coordinating heavy load permit assessments, making bridge load rating recommendations to the Principal Bridge Engineer and making recommendations for approval of new commercial vehicles to VicRoads. He has been involved with research, testing, and developmental work associated with standardisation of components for bridge and road structures and provides specialist support to the Department, other areas of VicRoads and external organisations.