Bridge Barriers – Implementing the AS5100 Bridge Design Code Provisions

By

Vincenzo Colosimo, B.Eng, G.Dip.CE, G.Dip.ME, MICE.
Bridge Loads Engineer – VicRoads Design

VicRoads

SYNOPSIS

Bridge Barriers have been the subject of extensive world wide 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 extremely important in order to improve road safety.

VicRoads has since October 1997 implemented guidelines for the design and performance selection of appropriate barriers relevant to site risk. Investigations for this work have drawn on international best practices and have formed the basis of the current Austroads et al. AS 5100 Australian Bridge Design Code (4) provisions. The Code provides guidance and direction for multiple performance level selection, design and acceptance of crashworthy barriers.

The 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 new or retrofitted barriers designed or upgraded where possible to conform with the requirements of the new code. It also details minor improvements to systems used aimed at fulfilling the code requirements and thus leading to possible future standards. In addition the paper outlines barrier options for the higher performance levels, which subject to prototype crashworthiness may be considered for approval, for specific uses.

Keywords: *bridge barriers, parapets, design, code, selection, containment, road safety*.

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1.0 INTRODUCTION

1.1 Background

Bridge barriers designed and built prior to 1970 generally do not meet current SA 5100 Bridge Code (3) requirements for multiple performance level barriers, with respect to design load and containment capacity. The older handrail type barriers include poor detailing such as posts which generally protrude in front of the rails creating potential traffic snagging hazards and end post monuments exposed to potential traffic impacts. Most of the older barriers designed up to 1997 do not conform to the appropriate performance level requirements of the new SA 5100 Code. VicRoads has since October 1997 implemented guidelines for the design and performance selection of appropriate barriers relevant to site risk and the requirements of the new Code.

This paper presents new, retrofitted or replacement barriers designed or upgraded where possible to conform with the requirements of the new code. Recent barrier systems have been based, where possible on details of tested barrier systems. Improvements have been incorporated by making minor modifications to the tested systems in order to produce recognisable multiple performance level barriers. This paper also details minor improvements to existing systems aimed at fulfilling the code requirements and thus leading to possible future standards. In addition the paper outlines barrier options for the higher performance levels, which subject to prototype crashworthiness may be considered for approval, for higher risk sites and specific uses.

1.2 Scope

The scope of this paper is to present barriers which fulfil requirements of the AS 5100 Code and include the following desirable features:

(a) Significant improvement for the protection of motorists in a collision through:

- Compatable transition and tensile continuity from road approach to bridge barrier
- Resistance to penetration by specified performance vehicles
- Presentation of a continuous barrier face to traffic
- Enhanced redirection capability for errant vehicles
- Prevention of snagging
- Improved energy absorption characteristics for retrofits to existing rigid barriers
- Detailed to minimise the risk of components spearing into vehicle passenger compartments or becoming airborne during an impact

(b) Retention of existing barriers where possible (except for timber barriers) for utilisation of their strength.
(c) Minimum aesthetic intrusion through simple unobtrusive detailing.
(d) Safe construction of retrofits and replacements with most of the work being able to be carried out from the bridge deck.
(e) Minimum cost through functional design and consideration of construction strategy.

2.0 AS5100 BRIDGE CODE PROVISIONS FOR MULTIPLE PERFORMANCE LEVELS

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

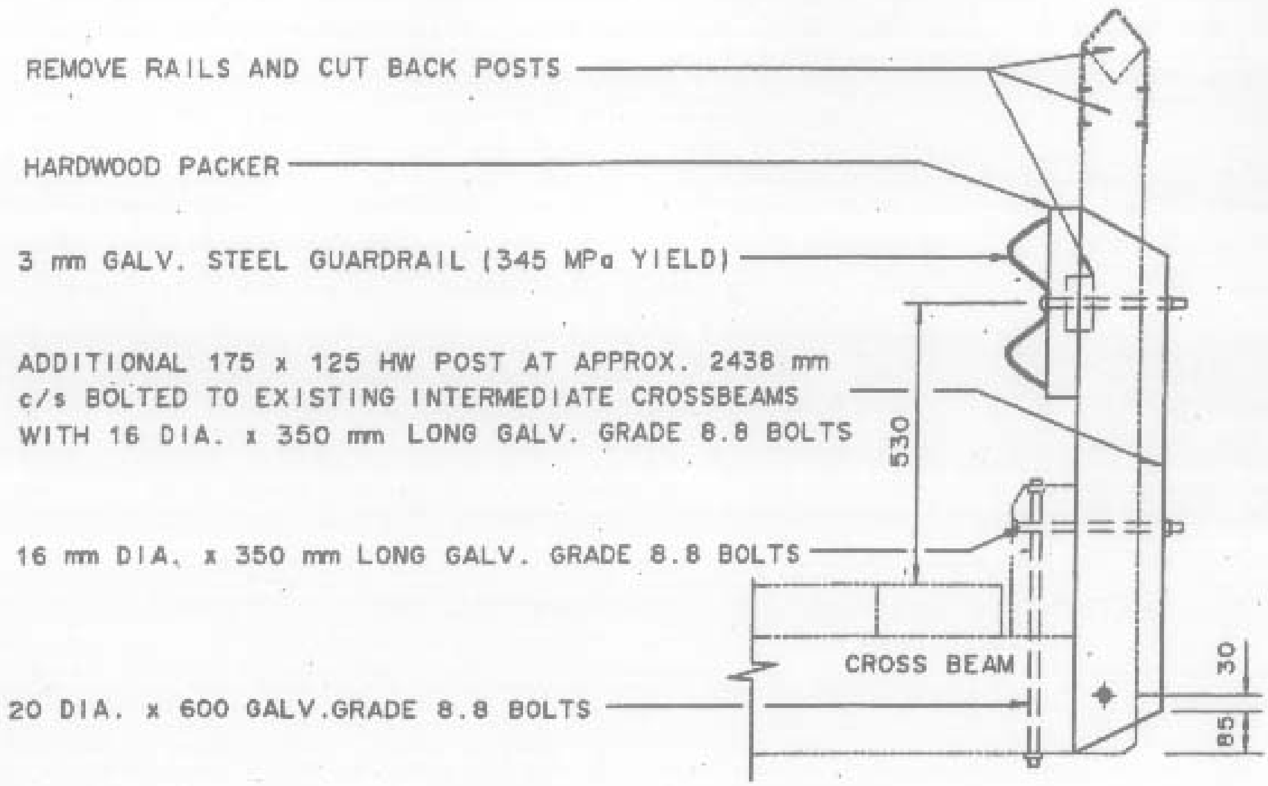


Fig. 1 - Standard Timber Handrail (Ref : 2/36)

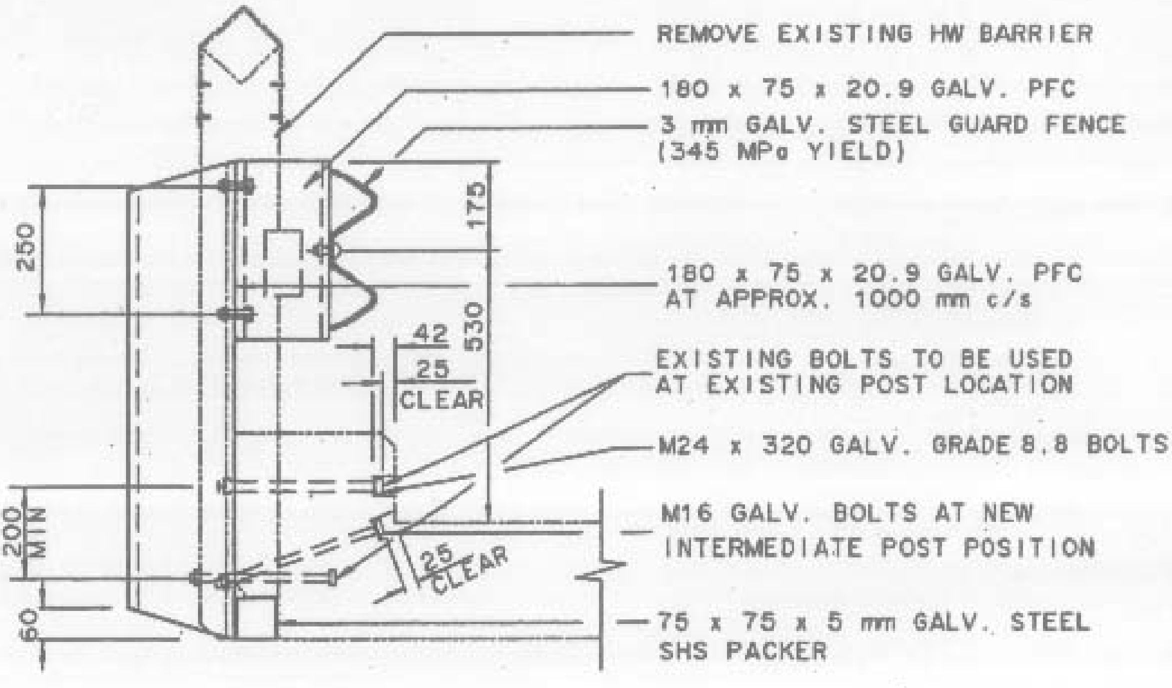


Fig. 2 - Timber Handrail for Concrete Bridges (Ref : 3/35)

The Bridge Code provisions are essentially based on rationalisation and extension of international practices including local research analysis and investigations. Results have been reported in previous papers and technical notes including references 6 to 10. These references should therefore be consulted for specific background information used to draft the barrier clauses in the Code. The Code specifies a number of barrier performance levels with the associated design and crash test requirements for each performance level (refer to Tables 1, 2 and 3).

The performance level and barrier type requirements for each site shall satisfy Code requirements and be to the approval of the relevant authority.

Notes:

1 Appendix B of the Code outlines a procedure for selecting the appropriate performance level for the more common types of bridge site risk parameters, such as alignment, location and traffic volume.

2 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.

2.1 No barrier

For certain bridge or culvert sites, conditions may be such that traffic barriers may constitute a higher risk than not providing any barrier e.g. traffic barriers need not be provided on low-level bridges subject to frequent flooding.

2.2 Low performance level

These barriers shall generally be provided for the effective containment of light vehicles and used for low risk sites, taking into account the speed environment e.g. low traffic volume, straight roads and bridges with narrow width and low height.

2.3 Regular performance level

Regular performance level barriers shall generally be provided for the effective containment of general traffic on all roads for the containment of light vehicles, utilities and light trucks.

2.4 Medium performance level

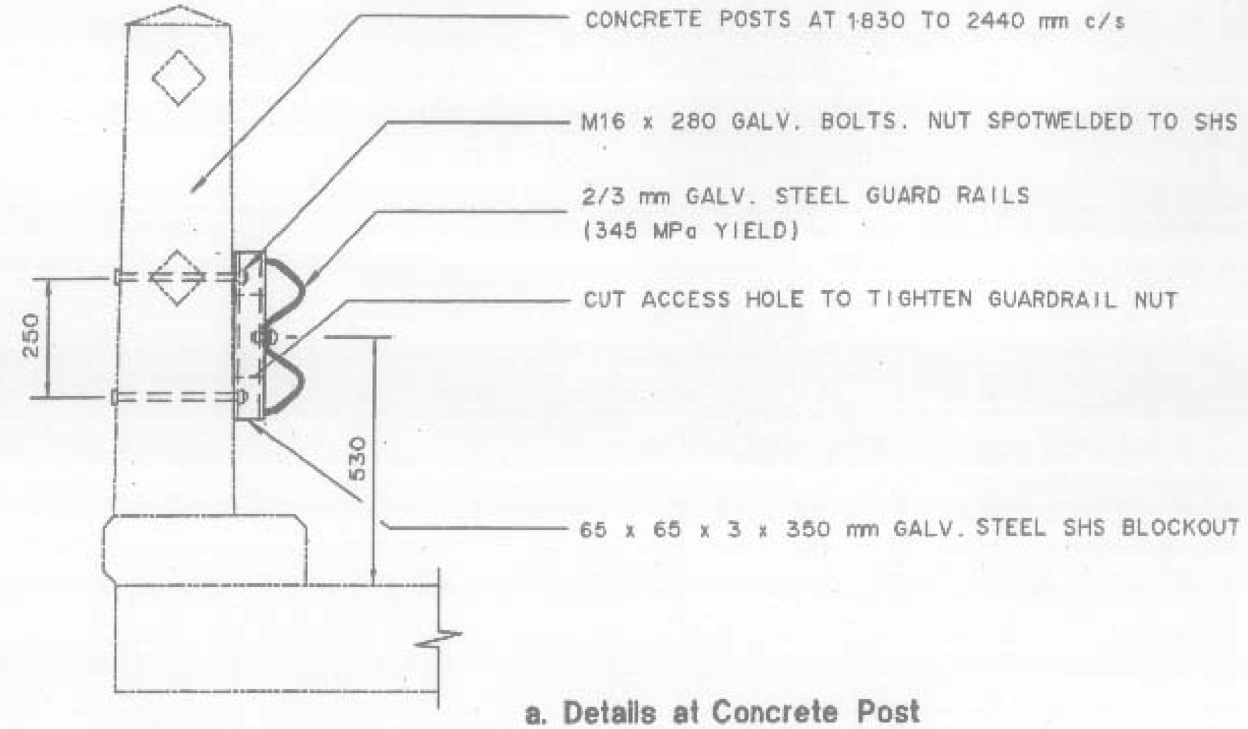
Medium performance level barriers shall be provided for site specific, medium to high risk situations for the effective containment of medium to high mass vehicles and buses on all roads.

2.5 Special performance level

Special performance level barriers shall 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 under various impact conditions needs to be prevented.

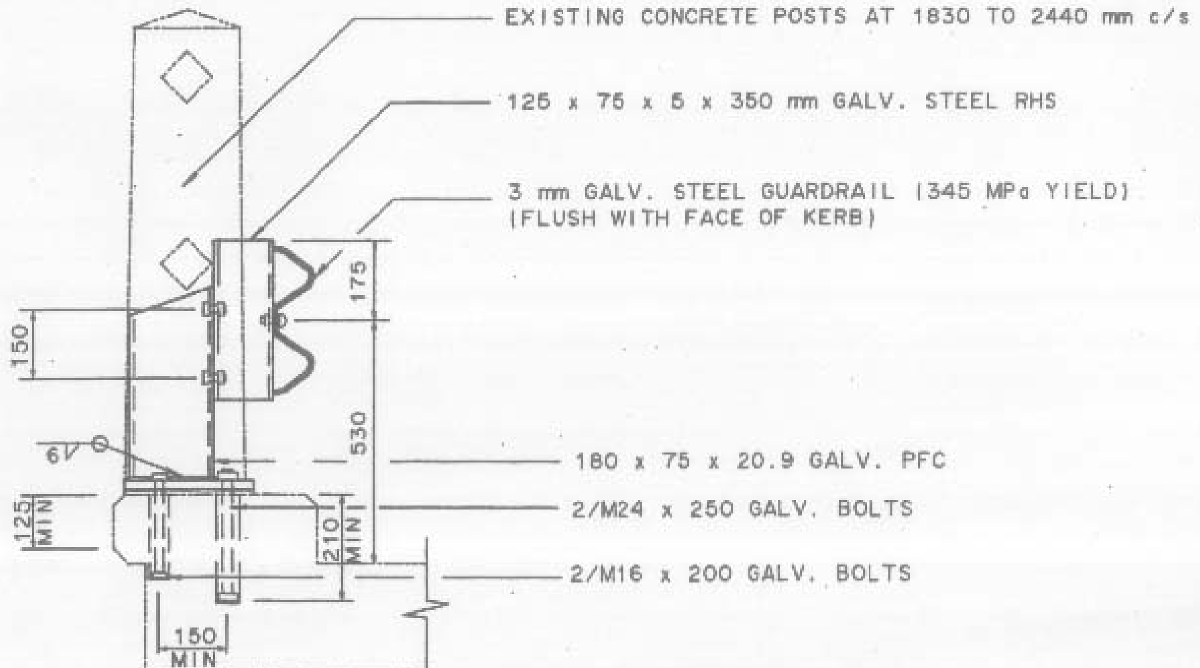
2.6 Crash Test Vehicles

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



a. Details at Concrete Post

Fig. 3 - Reinforced Concrete Handrail (Ref : 10/38)



b. Intermediate Post Details

Fig. 3 - Reinforced Concrete Handrail (Ref : 10/38)

Table 1 -Crash test vehicles and criteria for different performance level barriers

Barrier performance level	Vehicles	Test speed Km/h	Impact angle Degrees	TRB-NCHRP Report 350 test level
Low	0.8 t Small car 2.0 t Utility (see Note 1)	70 70	20 25	TL2
Regular	0.8 t Small car 2.0 t Utility 8 t Rigid truck (see Note 1)	100 100 80	20 25 15	TL4
Medium	0.8 t Small car 2.0 t Utility 36 t Articulated van (see Note 1)	100 100 80	20 25 15	TL5
Special	To be determined for specific site	Site specific	Site specific	(see Note 2)
e.g. High	0.8 t Small car 2.0 t Utility 44 t Articulated van (see Note 1)	100 100 100	20 25 15	(see Note 3)

NOTES:

1 Controlling strength test vehicles.

2 No equivalent Transportation Research Board Report (1993), TRB-NCHRP Report 350 test level.

3 No equivalent Transportation Research Board Report (1993), TRB-NCHRP Report 350 test level. 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.

2.7 Traffic Barrier Design Loads

The Ultimate Design Loads and distribution lengths for each Traffic barrier Performance Level are specified in Table 2. The AS5100 Code states that a load factor of 1.0 shall be used for these loads.

The Design Load is defined as an equivalent static load which represents the dynamic load imparted to a barrier system by a specified vehicle impacting the barrier at a specified speed and angle.

Table 2 - Design Loads and Contact Lengths

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

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.

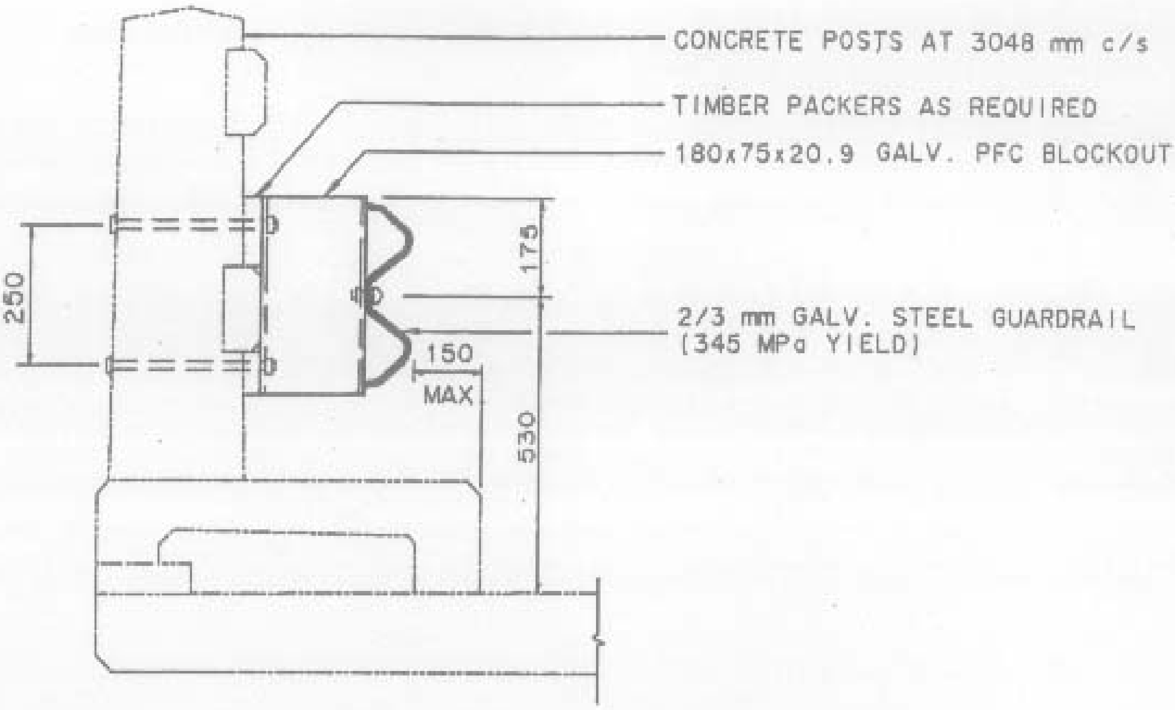


Fig. 4 - Reinforced Concrete Handrail Type 2 (Ref. 2/56)

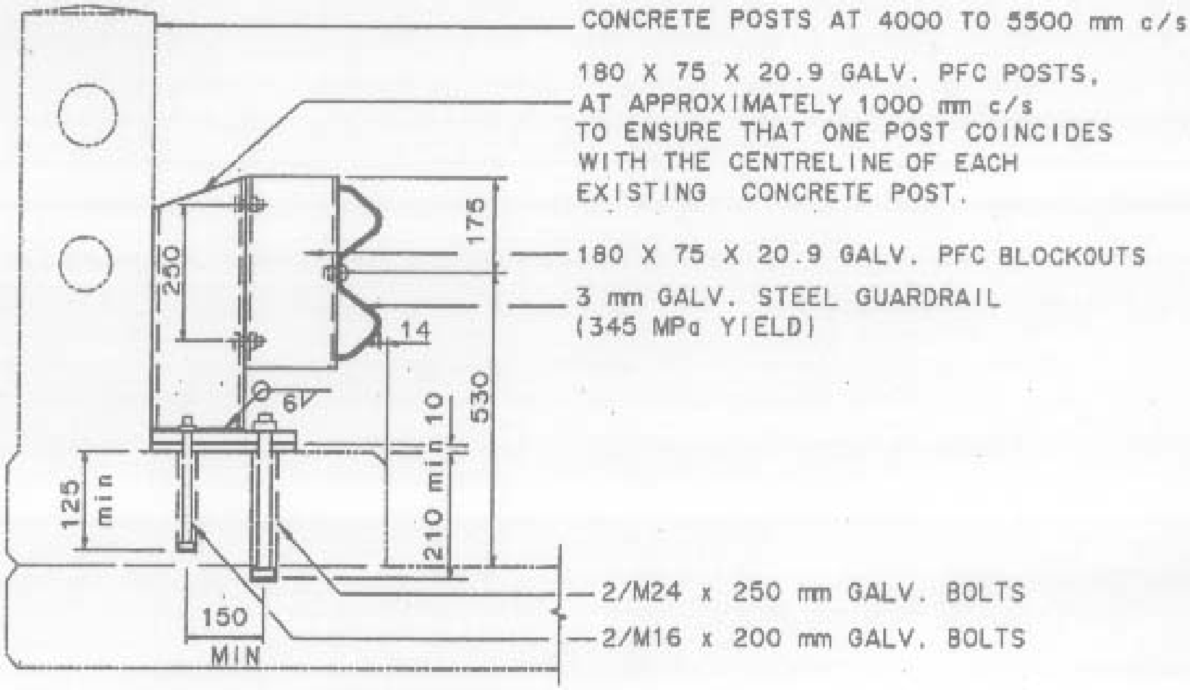


Fig. 5 _ Pipe Handrail (Ref. 1/62)

2.8 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 shall have an effective height greater than or equal to the required minimum effective height specified in Table 3.

Table 3 Traffic Barrier Minimum Effective Heights

Barrier Performance Level	Minimum Effective Height He mm
LOW	500
REGULAR	800
MEDIUM	1100
SPECIAL-High	1400

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

The designer should consider the ultimate behaviour of the barrier under impact including the potential for lateral rotation due to yielding of member sections with the resultant potential for vehicle ramping. For this purpose 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. The true height should be adjusted accordingly.

3.0 UPGRADING DEFICIENT LOW PERFORMANCE BRIDGE BARRIERS - OPTIONS

Bridge barriers built before 1970 do not meet modern requirements for safety, thus posing significant hazards to motorists. This Paper presents results of investigations and testing Colosimo 1992 (7), carried out to develop suitable strengthening measures for the various types of typical barriers in use, and reduce hazards caused by protruding posts. Strengthening proposals are based on the provision of a smooth high strength guardrail, continuous with the approach guardrail. Alternatives to strengthening involving more costly replacement options, aimed at achieving an appropriate performance level relevant to the site risk are also presented. These measures will reduce accident severity rates at bridges, while providing cost effective uniform practices.

Most of the pre -1970 bridge barriers consisted of low light panel systems suitable for upgrading to the Low Performance. However in the original investigation it was found that with provision of a rubbing guardrail it was generally possible to upgrade them to the traditional Road Side Barrier (Test Level 3) of the NCHRP R350 (11) containment capacity, with minimal additional cost. The following is a brief summary of the typical treatments, for the various types of existing deficient barriers. Additional modifications are included or described to fulfil the new performance levels.

Note that Information in brackets (...)* refers to VIC ROADS standard reference sheets. For example (Ref: 2/36) refers to standard sheet 2 produced in 1936.

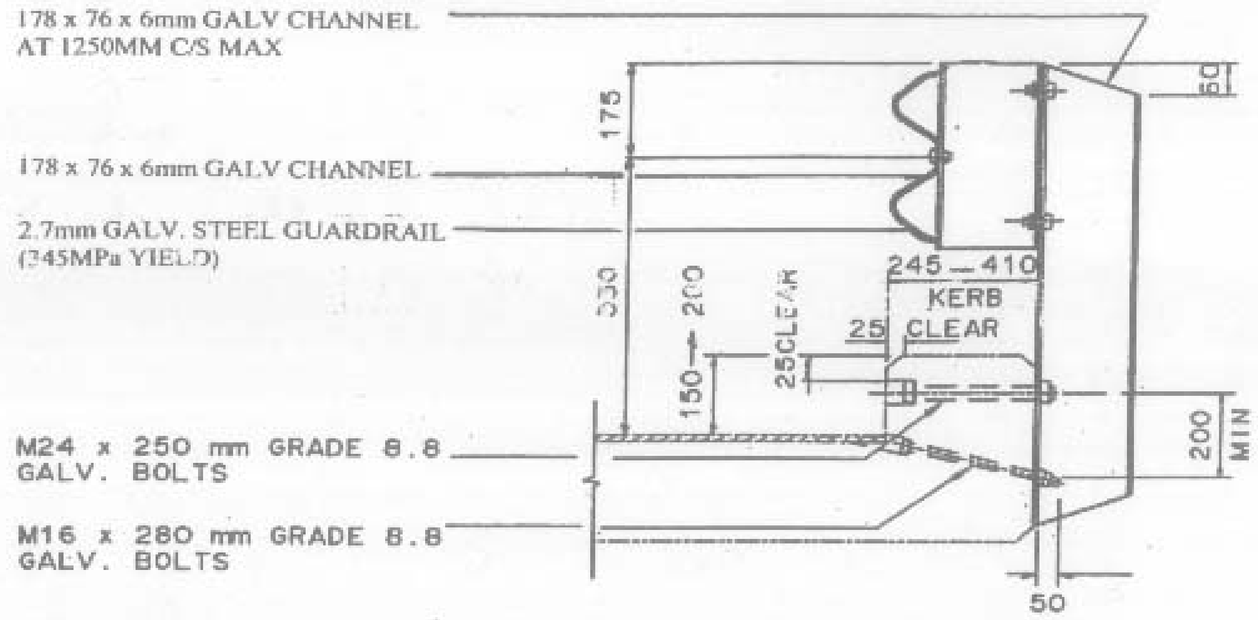


Fig.6 – Low Performance Barrier Replacement for Concrete Bridge Desks

Option 1 – Narrow Kerb

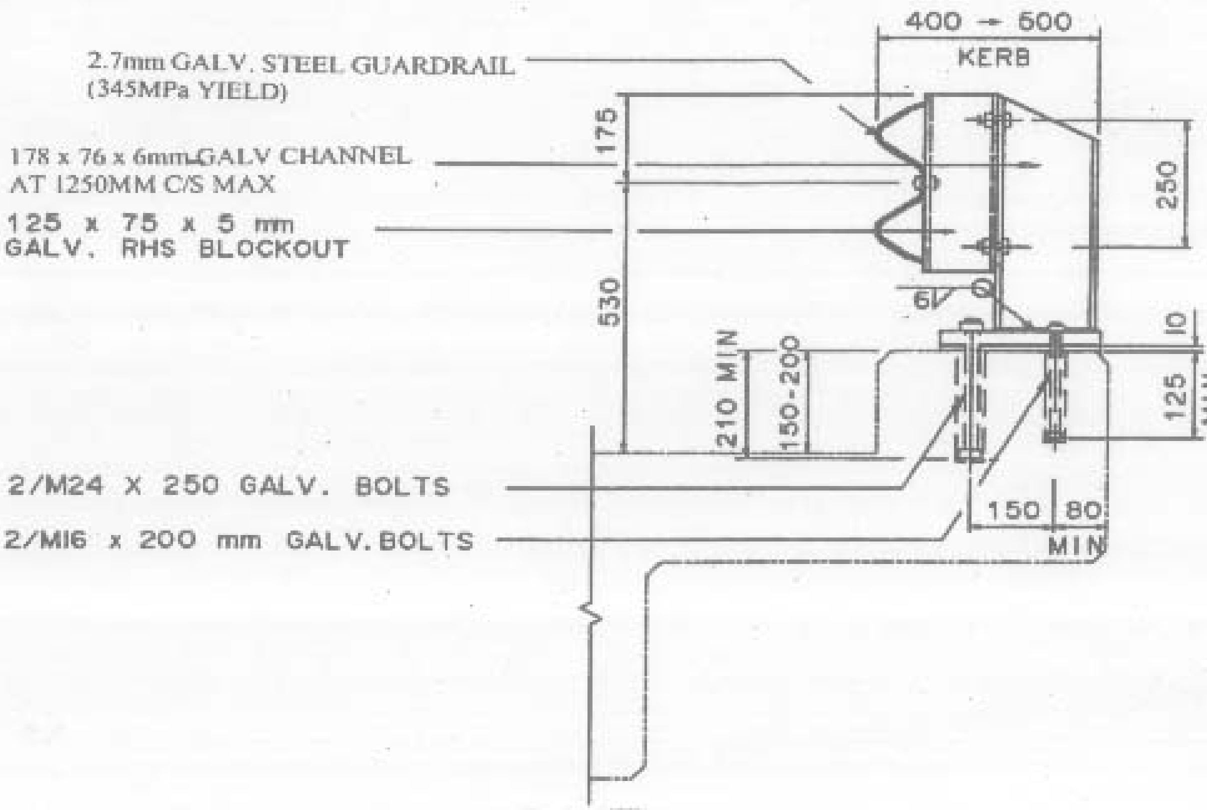


Fig.7 – Low Performance Barrier Replacement for Concrete Bridge Desks

Option 2 – Intermediate Kerb Widths

3.1 **Standard Timber Handrail** (Ref: 2/36)* (Fig. 1):

The option for timber structures is essentially a guardrail acting as a tensile rubbing rail, based on the strong beam-weak post principle. The new guardrail shown in Fig. 1 replaces the existing timber rails, thereby reducing snagging and spearing aspects of the existing railing, while providing tensile continuity for redirecting light vehicles.

This arrangements incorporates additional timber posts midway between the existing posts, thereby strengthening the barrier and improving its re-directional capacity. Two extra large washers are required for each bolt through timber, to minimise the potential for punching through the timber. The capacity of the guardrail can be marginally improved, by replacing the existing undersized timber posts (152 mm x 102 mm) with larger 175 mm x 125 mm hardwood sections, and increasing the size of connecting bolts.

The performance level for this arrangement due to its low height is Low. However with the full replacement of the timber posts it is considered that NCHRP-Test Level 3 light vehicles under 2 tonnes, impacting at standard crash conditions (namely 100 km/hr and 25 Degree incidence angle) will be redirected by this barrier.

3.2 **Timber Handrail for Concrete Bridges** (Ref: 3/35) (Fig. 2):

For this handrail treatment the guardrail is bolted to steel blockouts, which in turn are bolted to the steel posts. The steel posts are fixed to the kerbs by grouting bolts in position. At the existing post positions, the new parallel flange channel (PFC) posts are fixed to the existing bolts through square hollow section (SHS) packers. Anchorage capacity is improved by incorporating 76 mm x 76 mm x 6.3 mm steel packers, welded to the PFC posts.

The performance level for this arrangement due to its low height does not match the Regular Performance but will redirect Test Level 3 light vehicles under 2 tonne. However the barrier can be officially turned into a Low Performance Level by using lighter sized members. Sections can consist of 178x76x6 mm Grade 300 standard cold formed steel channel Posts at 1.25 m maximum spacing with a single guardrail (refer figures 6 & 7).

3.3 **Reinforced Concrete Handrail (Ref: 10/38) (Fig. 3) :**

The option shown is basically a continuous rubbing guardrail, fixed to the concrete posts through SHS steel blockouts. The access hole in the steel SHS is positioned on the departure side of the traffic. This hole is required for tightening the guardrail nut.

The single guardrail is weak in bending and may be strengthened to Test Level 3 vehicle capacity by doubling up the guardrail (Fig. 3a), or providing additional intermediate posts (Fig.3b). The arrangement in Fig. 3b is recommended. The barrier can also be replaced with details shown in Fig. 7, to fulfil the Low Performance Level.

3.4 **Reinforced Concrete Handrail** Type II (Ref: 2/56) (Fig 4):

This proposal is similar to the (Fig. 3) rubbing guardrail treatment, but allows for wider (180 mm) PFC blockouts, which in turn are bolted to the concrete posts through Hardwood packers, as shown in Fig. 4. The system has been previously installed without packers, which are considered optional.

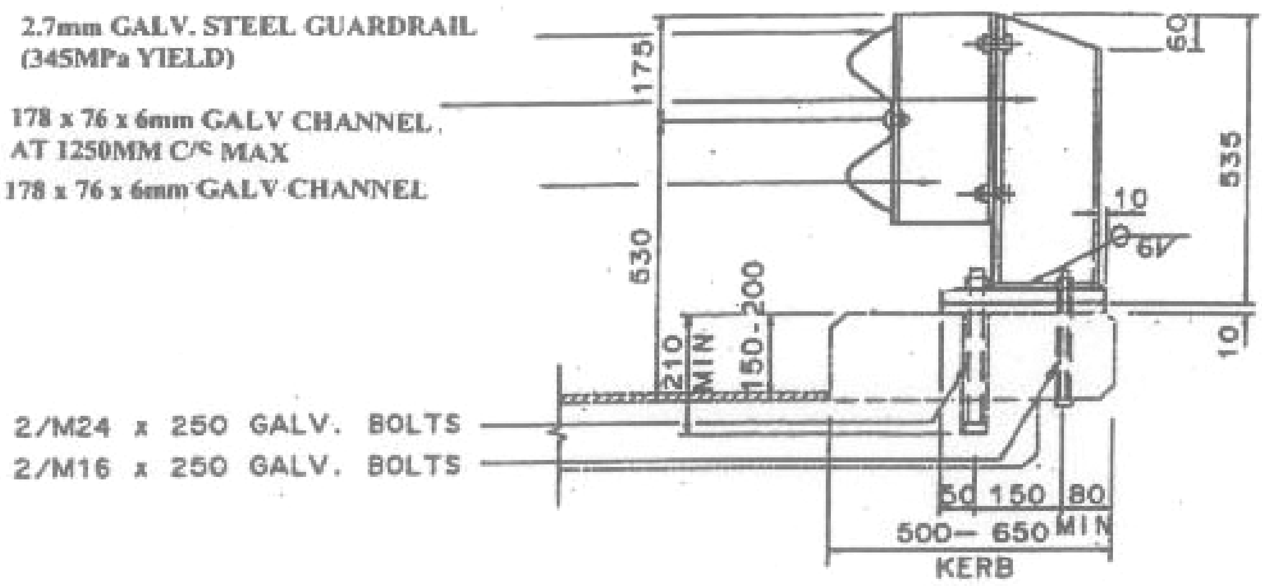


Fig.8 – Low Performance Barrier Replacement for Concrete Bridge Desks

Option 3 – Wide Kerb

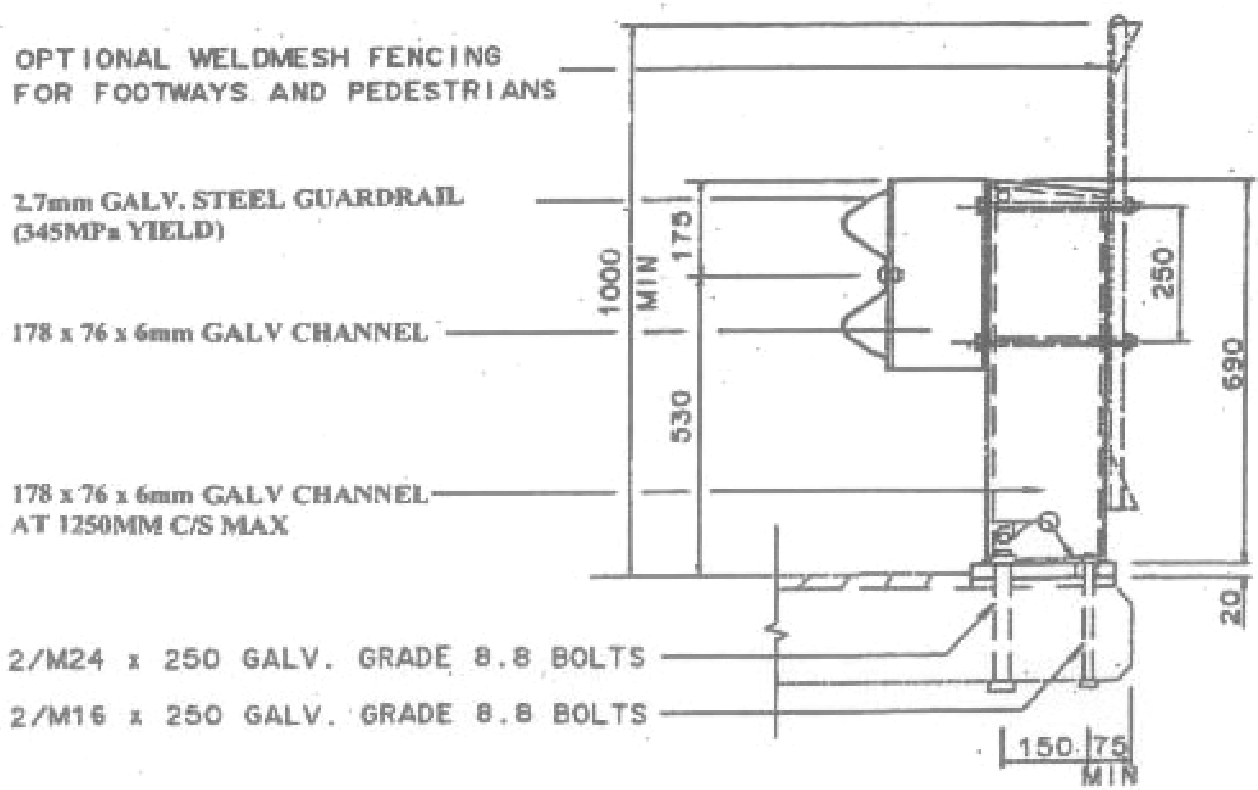


Fig.9 – Low Performance Barrier Replacement for Concrete Bridge Desks

Option 4 – Deck or Footway > 650 mm in Width

This system allows for partial removal of the precast kerb sections, with a resultant increase in trafficable deck width of approximately 160 mm.

Low Performance alternatives to this arrangement would be, to leave the kerb in position and replace the barrier with the barrier shown in Fig. 8 (with reduced width blockouts), or to replace both the barrier and kerbs by the barrier shown in Fig. 9. It is also possible to upgrade to the Regular Performance by adopting the arrangement shown in Figure 10 forwards of or replacing the existing barrier.

3.5 **Pipe Handrail** (Ref: 1/62) (Fig. 5):

The proposal shown in Fig. 5 essentially provides a rubbing guardrail, to avoid the potential for snagging of the existing system and improve vehicle redirection. The guardrail is further strengthened to Test Level 3 by fixing it to separate posts, at 1 to 1.25 metre centres.
It is possible to upgrade to the Regular Performance by adopting a marginally modified arrangement of that shown in Figure 10, forwards of or replacing the existing barrier.

3.6 **Barrier Replacement Options** (Fig. 6 to Fig. 10):

If it is considered that there is a warrant for completely replacing an existing deficient barrier, then proposals shown in Figures 6 to 9 may be utilised to fulfil the Low Performance Level.

The arrangement shown in Fig. 9 is suitable for decks without kerbs or wherever it is expedient to remove the existing kerb (eg. to increase the trafficable width of the bridge deck).

The arrangement shown in Fig. 10 is a more costly replacement alternative. This replacement option has sufficient height to satisfy the Regular Performance Level. It is based on a 'weak post-strong beam' principle. The top rail is meant to act in tension similar to a guardrail, and therefore is welded or spliced to form a continuous length over the structure and then transitioned/splayed down to the level of the guardrail at the approaches. The bottom guardrail allows continuation of the approach guardrail over the bridge for tensile continuity/anchorage and improved aesthetics.

4.0 BRIDGE APPROACHES

Severe decelerations and the consequent high risk of injury can occur if the transition from a flexible approach barrier to a rigid bridge barrier is not properly detailed and transitioned in strength.

A transition barrier shall be provided on the approach to all bridge barriers. A smooth face and tensile continuity shall be maintained throughout. Exposed rail ends, posts and sharp changes in the geometry of the barrier components, kerbs and similar shall be avoided or transitioned out with a maximum taper of 1 in 10 for the barrier components, and a maximum taper of 1 in 20 for the kerb discontinuities.

The performance level selection shall be based on the selection procedure referred to in the Draft Bridge Code (4) - Appendix A for successive cross sections on the approach. In addition the local site risk factors affecting the length of each performance level provision shall be considered.

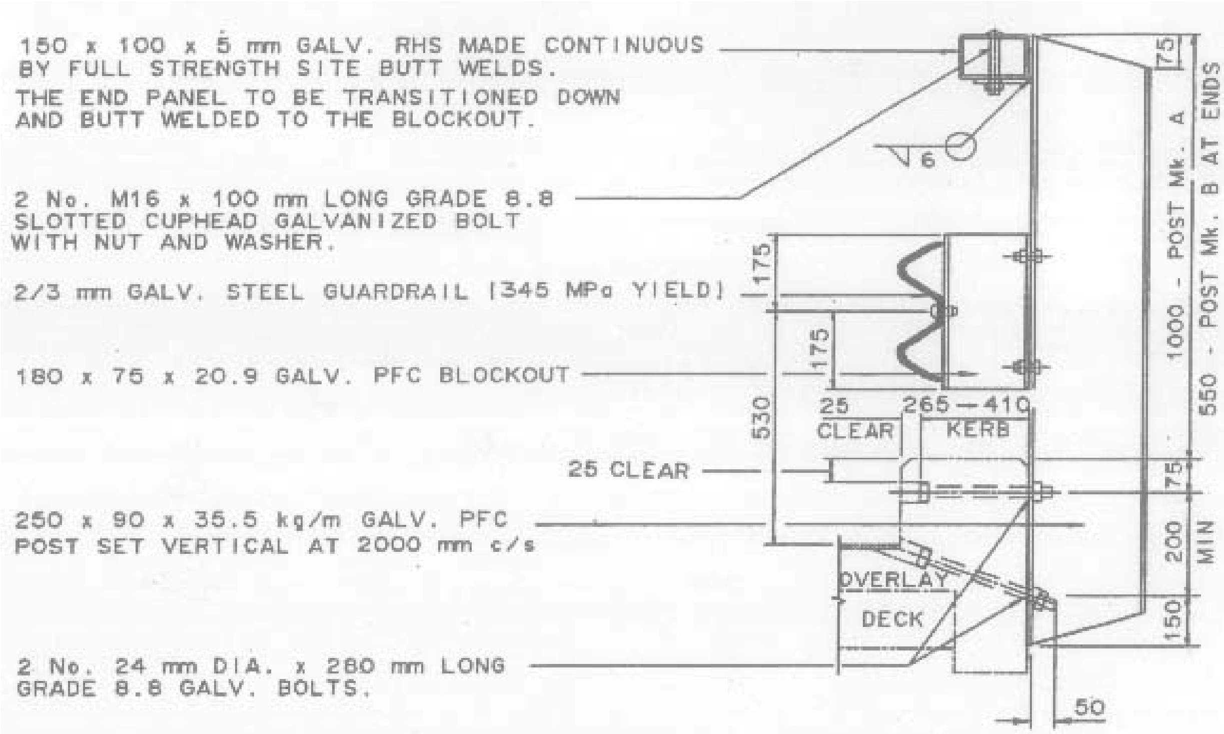


Fig. 10 - Barrier Replacement for Concrete bridge decks

Option 5 - Car and Bus Barrier

In existing urban areas or when city streets and/or footpaths prevent installation of the appropriate approach barrier system, consideration should be given to:

(a) Extending the bridge rail or approach barrier fence in such a manner as to prevent encroachment of a vehicle onto any highway system below the bridge;

(b) Providing traffic control measures such as speed restriction or intersection signs; or

(c) Providing recovery areas.

If the approach barrier is connected to a side road barrier, it should be continuous with the bridge approach barrier system and only a transition from the flexible to the rigid barrier system is required.

End Treatment - The approach end of a barrier shall have a crash worthy configuration, or be shielded by a crashworthy traffic barrier or impact attenuation device.

5.0 PROPOSED STANDARD BRIDGE BARRIERS

Considerable progress has already been made in developing a recommended range of standard barriers, which can be introduced as interim standards. Some options for the various Performance Levels are shown in Figure 11.

Tested barriers for relevant performance levels are indicated in Fig. 12. Recommended minor modifications/improvements are shown in dotted lines. These tested systems with minor modifications have formed a basis for our own standard barriers.

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

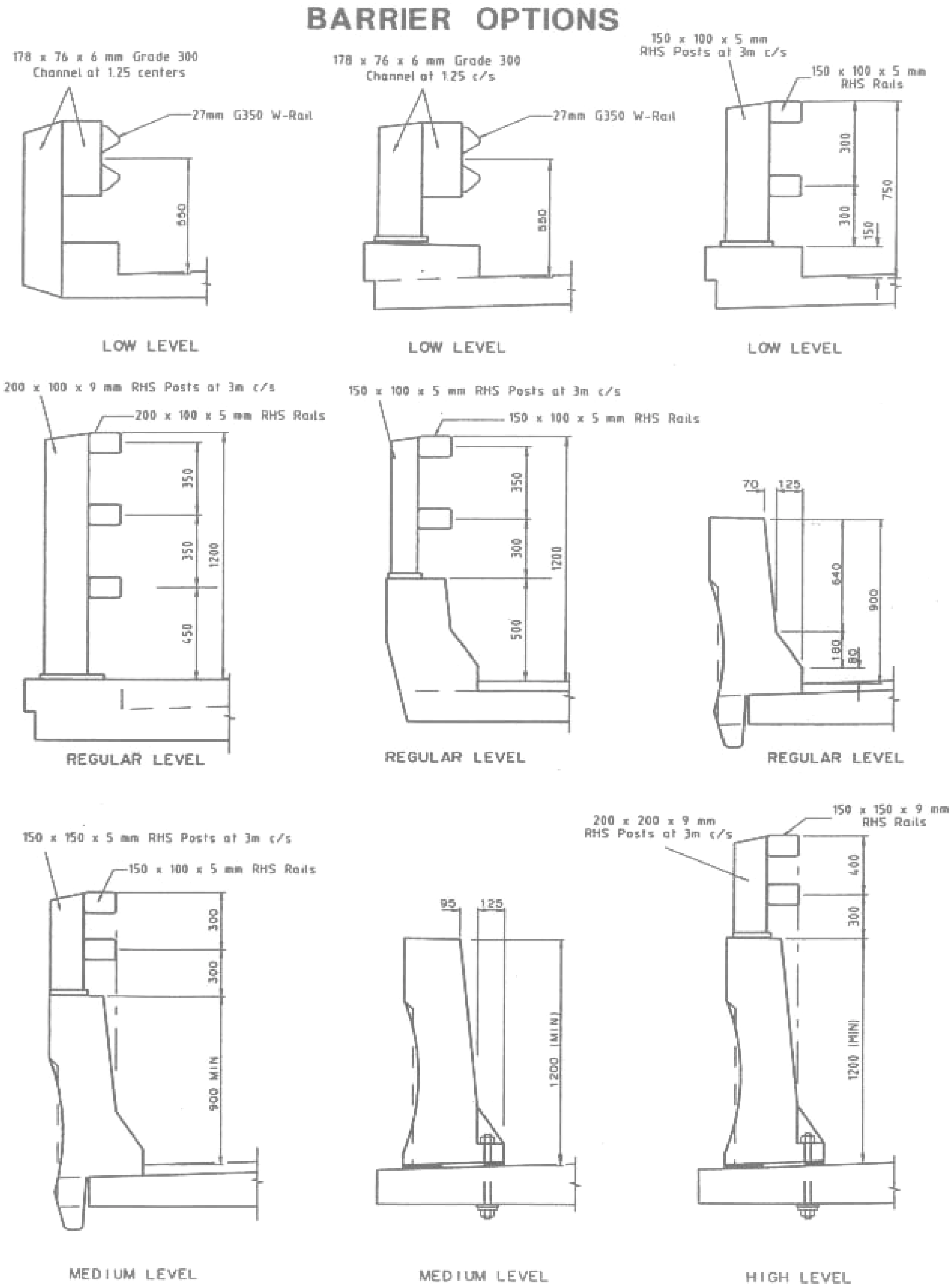


Fig. 11 - Barrier Options

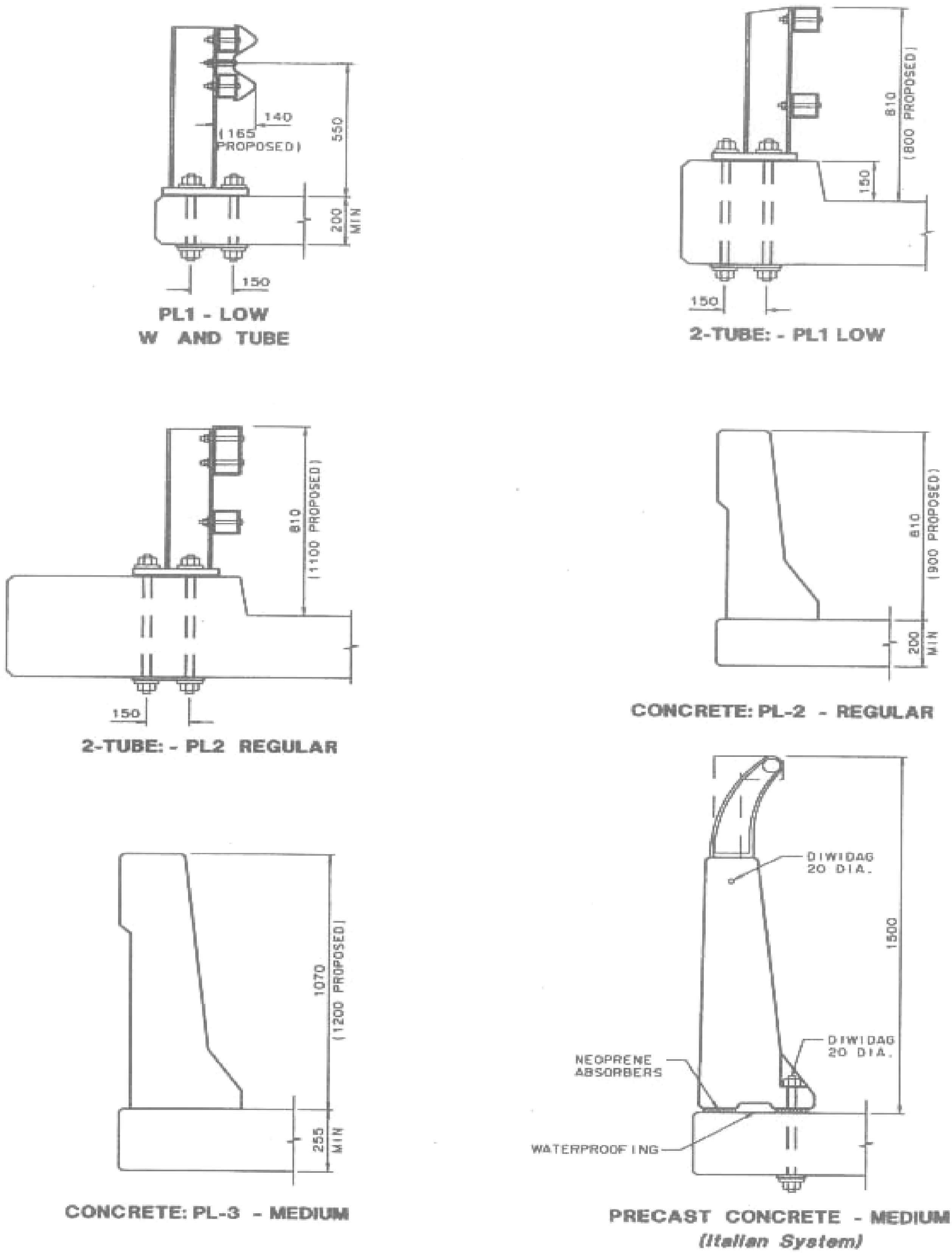


Fig. 12 - Tested Barriers
(AASHTO-AGC-ARTBA 1995)

6.0 COSTS

An estimate has been made of the cost of supply and erection of concrete barriers that would comply with the multiple performance levels nominated. These costs are $300, $400, $500 and $700 per linear metre for low, regular, medium and special-high performance level, concrete type barriers.

The equivalent costs for steel barriers would be expected to be in the order of $400, $550 and $700 per linear metre for low, regular and medium performance level. Note that the additional cost of providing a higher performance level barrier is small when compared to the overall bridge costs and the cost to the Australian community of approximately $1,500,000 per death and $300,000 per serious injury.

7.0 CONCLUSIONS

(i) The new AS 5100 Bridge Design Code provisions for Barriers will facilitate the design, approval and introduction of recognisable standard barriers for multiple performance level criteria. This will improve road safety and minimise litigation issues in respect to bridge barriers.

(ii) The upgrading proposals detailed in this paper have been developed, to provide suitable strengthening measures for the typical types of deficient barriers in use, and reduce hazards caused by protruding posts. Strengthening proposals are based on the provision of a smooth high strength guardrail, continuous with the approach guardrail. Alternatives to strengthening involving more costly replacement options are also presented.

(iii) It is proposed that barrier systems detailed in this paper with minor improvements form the basis of future Austroads approved Standards for national use.

8.0 **FUTURE DIRECTIONS**

(i) Prepare guidelines for performance selection and design of barriers to assist designers in implementing the Code requirements. The guideline to include structural requirements, performance levels and warrants for bridge approach barriers.

(ii) Develop and implement Guidelines for the assessment of Special high-risk site barriers.

(iii) Continue to develop a limited number of recognisable standard barriers based on the code provisions, associated guidelines and approved tested systems.

(iv) Carry out further simulation and where necessary prototype testing in order to gain Austroads approval and promulgation as standards, of the more promising barrier options.

(v) Provide expert advise on design of appropriate bridge barriers on a one off basis, during this development period.

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Vince Colosimo – BRIEF CV :

Vince Colosimo is an Engineer in the 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 has served as the Bridge Loads Engineer, responsible for heavy load permit assessments and load rating recommendations to the Principal Bridge Engineer. 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.