
Appendix B Barrier systems on structures

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B1 General

B1.1 General

This appendix provides guidance on types of barrier for traffic and vulnerable road users (ie pedestrians, cyclists and equestrians), their application and design and guidelines for determining appropriate barrier performance levels. The following topics are covered:

- B2 Types of barrier system and their applications
- B3 Barrier performance selection method
- B4 Barrier acceptance criteria
- B5 Standard traffic barrier solutions
- B6 Barrier system design criteria
- B7 Geometric layout (end treatment and transitions)

Median barriers on separated structures shall be treated as side protection.

B2 Types of barrier system and their applications

B2.1 General

The selection of an appropriate road safety barrier system for any structure is an important safety process. The level of protection should be not less than that provided at the roadside on the approaches to the structure and any hazard protected by that barrier. This level of protection should be applied to the 'length of need' required to adequately protect the hazard (*Austrroads Guide to road design Part 6 Roadside design, safety and barriers*⁽¹⁾).

The road safety barrier system shall consist of one of the alternatives detailed below for each situation except where a 'no barrier' solution is deemed acceptable in accordance with B3.1.6. The required road safety barrier performance level and subsequent barrier selection shall be appropriate to that required by any roadside hazard in the vicinity of the structure and take into account traffic (B3), pedestrian presence (B2.4), cyclist and equestrian presence (B2.5) and provision for the occasional presence of people (B2.9).

NZTA M23 *Specification for road safety barrier systems*⁽²⁾ covers road safety barrier systems accepted for installation on the state highway network.

Structures shall comply with the clause F4 *Safety from falling* requirements of the *Building code*⁽³⁾. Clause F4 requires barriers of "appropriate height" to be installed so that structures are "constructed to reduce the likelihood of accidental fall". This may include the provision of barriers specifically for pedestrians and other vulnerable road users.

B2.2 Semi-rigid barrier

A semi-rigid barrier is defined as a post and continuous rail system which restrains vehicles by absorbing energy during deformation of the system and of the vehicle.

B2.3 Rigid barrier

A rigid barrier is defined as a barrier designed so that there will be no movement of the barrier system, other than elastic straining during a crash involving the design vehicle. They include continuous concrete barriers and metal post and rail systems that behave in a rigid manner. Rigid barriers shall be used in preference to semi-rigid barriers in the following situations:

- i. For architectural consistency, where rigid barriers are used on the approaches.
- ii. Where it is necessary to provide additional protection for a particularly vulnerable structural element or sensitive hazard (TL-5 and greater).
- iii. Where deflection of a semi-rigid barrier system cannot be accommodated or is undesirable.

B2.4 Pedestrian barrier

A pedestrian barrier is defined as a post and rail system that restrains pedestrians. Pedestrian barriers may be of two types:

- General type, which consists of a series of posts supporting a top rail, below which is any system of members between which the spaces are not more than 300mm in at least one direction.
- Vertical bar type, which consists of a series of posts supporting a top rail, below which are vertical bars, between which the spaces are not more than 100mm. The vertical bars shall be attached only at the top and bottom.

Barriers of both types shall have a minimum height to the top edge of the top rail of 1100mm and shall comply with *New Zealand building code* acceptable solution F4/AS1⁽⁴⁾.

Pedestrian barriers shall not be used for the restraint of vehicles and should only be used in the following locations:

- on a structure provided for the sole use of pedestrians, ie not motorised traffic
- on the outside of a footpath on a structure that is separated from the motorised traffic by a semi-rigid barrier or a rigid barrier.

The vertical bar type shall be used in the following situations:

- i. In locations where children less than six years of age are expected to frequent the structure or on known or nominated school walking routes.
- ii. Where the structure crosses over or is above building properties, city streets, main highways, motorways, or railways.
- iii. Where the footpath is at a general height of more than 5m above ground or water level.
- iv. Where the volume of pedestrian traffic is exceptionally heavy or likely to become so.
- v. Where there are circumstances likely to cause alarm to pedestrians, such as a river prone to violent, rapid flooding, that demand a higher level of pedestrian protection be provided.

The general type may be used elsewhere.

B2.5 Cyclist and equestrian barriers

The principles described in B2.4 also apply to the protection of cyclists and equestrians, with barriers similarly only being used on dedicated structures or outside of paths on structures that are separated from motorised traffic by a semi-rigid barrier or a rigid barrier.

The minimum height to the top edge of the top rail for a cyclist barrier shall be 1400mm and for an equestrian barrier 1800mm. A 600mm high solid infill panel shall be provided at the bottom of an equestrian barrier to obstruct a horse's view of the void below.

Cyclist and equestrian barriers should be designed appropriately in accordance with B6.4. Unless specified otherwise, cyclist and equestrian barriers should also incorporate the relevant requirements for pedestrians as required by the B2.4.

B2.6 Combination barrier

A combination barrier shall satisfy the requirements for a traffic barrier and shall provide additional protection for vulnerable road users as required, typically through adding additional rails or increasing the traffic barrier height. This may be where extra provision for safety from falling is required or where significant pedestrian, cyclist or equestrian presence is anticipated.

Having established the level of protection to be provided for the hazards presented to traffic, consideration must be given to the additional protection required when there are significant numbers of vulnerable road users anticipated or specific facilities provided for them. Depending on the facility provided, the additional design requirements are in B6.

B2.6 continued	The provision of specific facilities for pedestrians, cyclists and equestrians within the bridge cross-section is covered by appendix A.
B2.7 Barrier kerb	<p>A barrier kerb is defined as a high kerb that protects pedestrians by restraining the wheels of vehicles. Historically, this type of kerb was typically used adjacent to a footpath and provided additional restraint to errant vehicles because the side protection on the bridge was inadequate.</p> <p>Barrier kerbs shall not be used on new structures. They may only be used on existing structures in exceptional circumstances with the agreement of the road controlling authority.</p>
B2.8 Barrier configurations for specific situations	<p>a. Traffic lane (with shoulder) adjacent to deck edge:</p> <ol style="list-style-type: none"> i. semi-rigid barrier ii. rigid barrier (eg concrete with or without top rail or metal post and rail). <p>b. Traffic lane (with shoulder) adjacent to footpath:</p> <ol style="list-style-type: none"> i. The use of a kerb between the carriageway and the footpath requires a semi-rigid or rigid barrier at the outer edge of the footpath. ii. Semi-rigid or rigid barrier between the carriageway and the footpath requires a pedestrian, cyclist or equestrian barrier at the outer edge of the footpath. <p>c. Separated (off-road) footpath, cycle path or bridle path:</p> <ol style="list-style-type: none"> i. Semi-rigid barrier or combination barrier between the carriageway and the footpath requires a pedestrian/cyclist/equestrian barrier at the outer edge of the footpath. ii. Rigid barrier (with or without additional rail) between the carriageway and the footpath requires a pedestrian/cyclist/equestrian barrier at the outer edge of the footpath. <p>The standard cross-sections shown in figure A1 illustrate various possible combinations of these alternatives.</p>
B2.9 Provision for the occasional presence of people	<p>Where no specific footpath or barrier provisions for vulnerable road users are provided on a structure, barriers with a minimum height to the top edge of the top rail of 900mm shall be provided unless:</p> <ul style="list-style-type: none"> • a 'no barrier' solution is deemed acceptable in accordance with B3.1.6 • barriers are otherwise agreed to not be required by the road controlling authority • a risk assessment determines that alternative lower height barrier provisions are appropriate as the likely number of vulnerable road users on the structure is very low or the hazard being protected is of low risk • a risk assessment determines that higher height barrier provisions are required. <p>These barriers are to allow for the presence of road users such as inspection, maintenance and emergency personnel and pedestrians in a remote rural environment, termed as allowing for the "occasional presence of people" for the purposes of this clause.</p> <p>Any risk assessment undertaken shall take due consideration of the requirements of the clause F4 <i>Safety from falling</i> requirements of the <i>Building code</i>⁽³⁾ and the MBIE <i>Best practice guidelines for working at height in New Zealand</i>⁽⁵⁾ and shall be presented for agreement by the road controlling authority in the structure options report and structure design statement as details are developed.</p> <p>Traffic safety barriers or combination barriers are considered acceptable provision for the occasional presence of people. The use of modified Thrie Beam barrier (865mm high), as detailed in table B2, is also generally considered acceptable.</p>

B3 Barrier performance selection method

A risk assessment approach shall be used to indicate the likely traffic barrier performance level required at a structure site. This assessment must consider both the structure and the associated approaches.

The NCHRP Report 350 *Recommended procedures for the safety performance evaluation of highway features*⁽⁶⁾ test level corresponding to each barrier performance level is presented in table B1.

Table B1: Barrier performance levels and equivalent NCHRP Report 350⁽⁶⁾ test levels

Barrier performance level	Equivalent NCHRP Report 350 ⁽⁶⁾ test level
Special	No equivalent test
6	TL-6
5	TL-5
4	TL-4
3	TL-3

This risk assessment approach applies to barriers for new structures and replacement barriers for existing structures. It provides a barrier selection method based on a risk approach that encompasses traffic conditions and the structure environment.

This method focuses on the exposure to the risk, ie traffic volume, rather than the severity of outcome. Therefore B3.1 also provides specific criteria for the selection of an appropriate barrier performance level based on severity of outcome.

Figure B1 is to be followed for the selection of an appropriate barrier at a particular structure location.

B3.1 Performance levels

B3.1.1 General

The performance of the edge protection (barrier) system should be commensurate with the object being protected from the traffic or that the traffic is being prevented from hitting. The philosophy applied to assess the performance level should be consistent with that applied to the adjacent highway network.

There are five test levels available to the designer depending on the context of the structure. These range from the minimum TL-3 (not usually allowable on new state highway structures) to a 'special performance' barrier designed to protect a specific hazard and vehicle.

The following sections describe the context requiring each level of protection. Designers should start with the conditions requiring TL-5 and then work through to TL-3 as necessary. Should the requirements for a TL-5 barrier be exceeded (B3.1.2) then a full risk assessment should be carried out as part of the selection of a TL-6 or 'special performance' barrier system.

The requirements for the occasional presence of people given in B2.9 should be noted.

B3.1.2 Barrier performance level 5

A barrier performance level 5 barrier shall be the standard side protection barrier for structures carrying a divided multi-lane state highway.

B3.1 continued

A barrier performance level 5 barrier provides for the containment of buses and medium mass vehicles on high speed carriageways, major carriageways, and urban roads with a medium to high level of mixed heavy vehicles, and site specific risk situations.

A barrier performance level 5 barrier system shall be provided as edge protection for a structure where the number of commercial vehicles passing over the structure exceeds either of the following values:

- a. on roads with a posted speed limit greater than 60km/h: 2000 heavy commercial vehicles per day, or
- b. on roads with a posted speed limit of 60km/h or less: 4000 heavy commercial vehicles per day.

A barrier performance level 5 barrier system shall be provided as edge protection for a structure where one or more of the following conditions exist on the road or hazard being spanned by the structure:

- c. major roads with AADT (annual average daily traffic) of 10,000 or more vehicles per day (vpd)/lane, or
- d. roads with AADT of 40,000 or more vpd, or
- e. electrified railways, or over goods lines carrying significant quantities of either noxious or flammable substances, or
- f. high occupancy land such as houses, factories, areas for congregating, etc.
- g. the height differential is more than 10 metres
- h. water depth is greater than 3 metres
- i. the highway crossing the structure is on a horizontal curve with a radius of 600m or less.

The AADT referred to above is the estimated construction year AADT (refer to B3.2 for further explanation of this). Refer B3.2.3 for heavy commercial vehicle definitions.

Consideration should only be given to use of a higher performance level barrier if the conditions detailed in B3.1.5 apply.

B3.1.3 Barrier performance level 4

A barrier performance level 4 barrier provides for the appropriate containment of cars, heavy utilities and light to medium mass commercial vehicles on main (single lane) carriageways.

This is the minimum standard acceptable for all new state highway structures unless site specific acceptance is obtained from the National Manager Traffic & Safety.

B3.1.4 Barrier performance level 3

A barrier performance level 3 barrier provides for the safe containment of light vehicles, with occasional use by medium-heavy commercial vehicles, such as stock trucks and/or farm equipment.

These barriers should generally be considered for use on structures on non-state highway rural roads:

- a. with low traffic volumes (typically less than 500vpd) and in low speed environments (70km/h or less); or
- b. short structures (<10m) with low height above ground (<1.5m), or across shallow water (<1.0m).

B3.1 continued

B3.1.5 Special barrier performance level (test level 6 and above)

1. Barrier performance level 6

A barrier performance level 6 barrier shall only be provided at specific locations where agreed by the road controlling authority, where there is a high probability of loss of life or serious injury due to a vehicle penetrating the barrier.

A barrier performance level 6 barrier shall be only be considered if the commercial traffic volume criteria detailed for barrier performance level 5 (refer B3.1.2(a) and (b)) are expected to be exceeded for sustained periods and any of the crossed environment or height conditions stated in B3.1.2(c) to (i) apply, subject to an appropriate risk and benefit-cost analysis justification to the *NZTA Economic evaluation manual*⁽⁷⁾.

2. Special barrier performance

A special performance level, non-penetrable barrier shall only be provided at specific locations where agreed by the road controlling authority, where vaulting by high mass and high centre of gravity vehicles must be prevented.

Such a barrier shall be considered if the commercial traffic volume criteria detailed for barrier performance level 5 (refer B3.1.2(a) and (b)) are expected to be exceeded for sustained periods and at least two of the crossed environment or height conditions stated in B3.1.2(c) to (i) apply at the same time, subject to benefit-cost justification.

There is no equivalent NCHRP Report 350⁽⁶⁾ test level for this performance level. A 44t articulated heavy commercial vehicle (HCV) shall be the controlling vehicle in determining barrier strength with the remaining test requirements as per TL-6 (NCHRP Report 350⁽⁶⁾).

B3.1.6 'No barrier' option

For certain structure sites, conditions may be such that the presence of a barrier constitutes a risk that is higher than or similar to the hazard being protected. Consideration may therefore be given to omitting barriers where all the following conditions are satisfied (noting that the requirements of the *Building code*⁽³⁾, to safeguard people from injury caused by falling, can be complied with even if no barrier is provided):

- there are no barriers on the approaches to the structure
- conditions under and near the structure do not increase the level of risk to the occupants of the vehicle leaving the structure
- the edge of the structure is less than 1.5m above the ground
- water beneath the structure is less than 1m deep
- traffic volumes are less than 150 vehicles per day
- the radius of curvature at the structure site is greater than 1500m and the road approaches have visibility greater than the required stopping sight distance
- the location is rural and without provision for pedestrian traffic
- the bridge or structure is less than 5m long in the direction of travel and the deck extends at least 1.2m laterally beyond the carriageway edge.

When the edge of the structure is greater than 9 metres from the edge of the carriageway, or when a culvert is less than 3.4m² and has ends flush with the embankment slope, a risk assessment should be carried out in accordance with the *Austroroads Guide to road design* part 6⁽¹⁾.

B3.1 continued

Where a 'no barrier' option is proposed, details shall be presented for agreement by the road controlling authority in the structure options report and structure design statement as details are developed.

**B3.2 Adjusted
AADT method for
barrier performance
levels 3, 4 and 5
selection**

B3.2.1 General

Once it has been determined that a barrier is required, if the context of the structure does not require a barrier performance level 5 or 6, or a special performance barrier, the appropriate performance level shall also be assessed using the adjusted AADT method outlined in AS 5100.1 *Bridge design* part 1 Scope and general principles⁽⁸⁾ section B4, with modifications detailed in this manual to account for New Zealand conditions, and as indicated in figure B1. This method assumes 2% traffic growth per annum over 30 years.

Where there is a difference between the test level determined using B3.1 and this 'Adjusted AADT method', the greater of the two test levels should be adopted.

The adjusted AADT method shall be used as follows:

- i. If the estimated traffic growth is 2% per annum then AS 5100.1⁽⁸⁾ section B4 with the following amendments can be used directly.
- ii. For growth rates other than 2% per annum the construction year AADT for use in this section can be estimated by dividing the 30-year after construction AADT by 1.81. The error in using this estimation is acceptable and within the assumptions of this methodology.

The adjusted AADT shall be calculated as follows:

$$\text{Adjusted AADT} = RT \times GD \times CU \times US \times \text{AADT}$$

Where: RT = Road type factor (from AS 5100.1⁽⁸⁾ table B1).

GD = Road grade factor (from AS 5100.1⁽⁸⁾ figure B2).

CU = Curvature factor (from figure B2 of this manual).

For radius of curvature less than 600m refer to section B3.1.2 of this manual.

US = Deck height and under-structure conditions factor (from AS 5100.1⁽⁸⁾ figure B4) for the risks described in AS 5100.1⁽⁸⁾ section B4.2.5.

AADT = AADT in construction year

The AADT is the total traffic volume for all lanes in both directions crossing the structure.

B3.2.2 Final barrier performance level selection

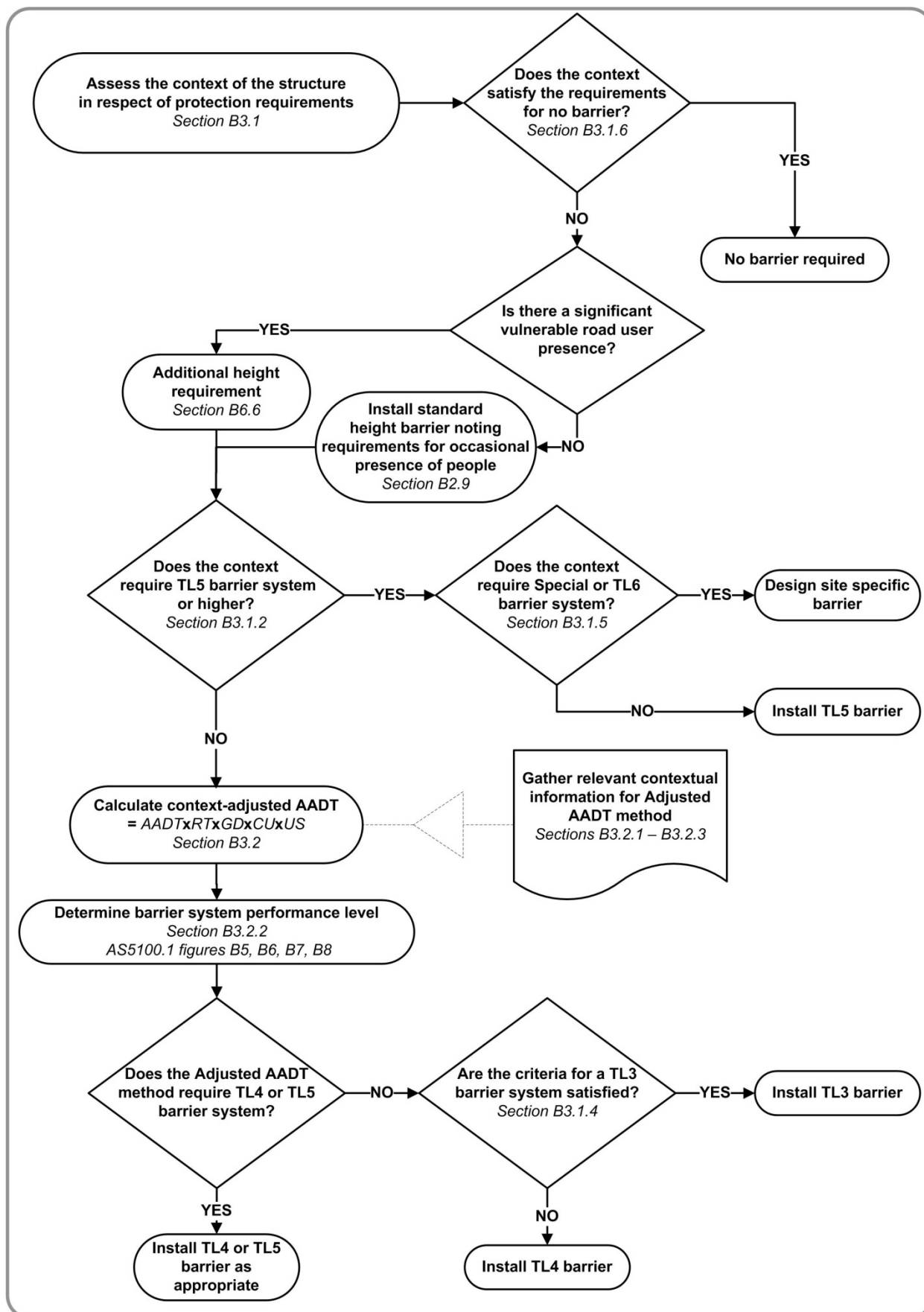
The final barrier performance level is selected by comparing the adjusted AADT with the threshold limits for the appropriate design speed given in AS 5100.1⁽⁸⁾ figures B5 to B8. These threshold graphs also include an additional variable to cater for the offset from the face of the barrier to the edge of the traffic lane, described as rail offset in the charts.

Note that a 'rail offset' of 0.3m shall be assumed in all instances for the purposes of this clause.

The barrier performance levels described in AS 5100.1⁽⁸⁾ figures B5 to B8 shall be substituted as follows:

- Replace "Medium Level" by "Barrier performance level 5"
- Replace "Regular Level" by "Barrier performance level 4"
- Replace "Low Level" by "Barrier performance level 3".

Figure B1: Traffic barrier performance selection flow chart



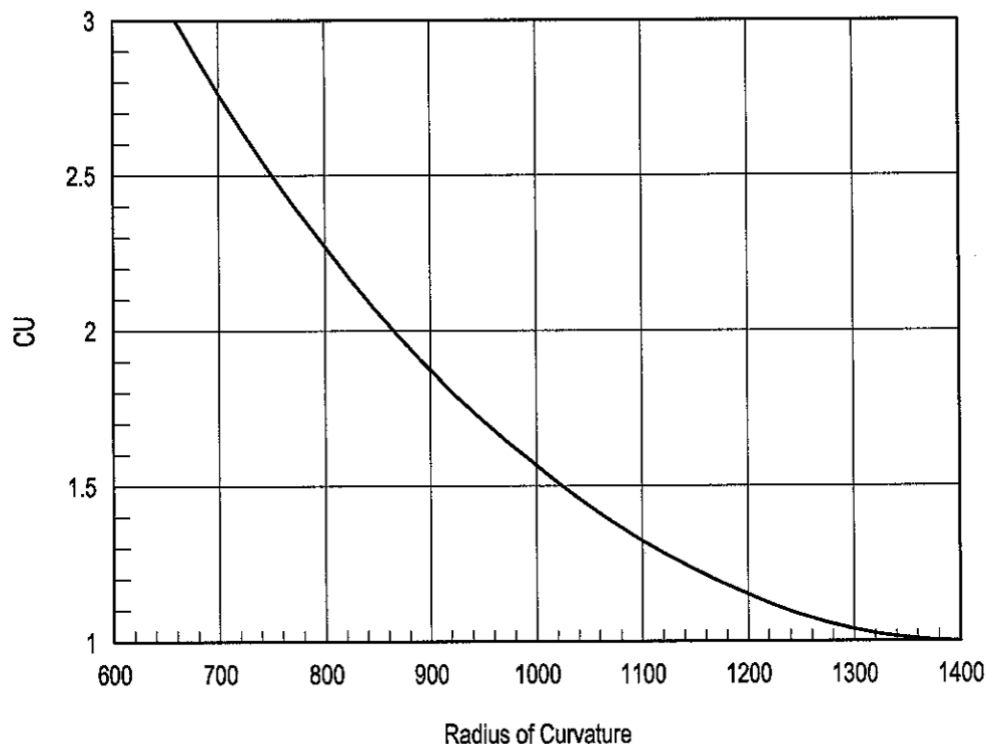
B3.2 continued

B3.2.3 Vehicles and traffic mix

The percentage of commercial vehicles in AS 5100.1⁽⁸⁾ figures B5 to B8 includes medium to heavy commercial vehicles (ie MCV to HCVII as described in the NZTA's *Economic evaluation manual*⁽⁷⁾).

For locations where the commercial vehicle (MCV to HCVII) traffic mix exceeds 40% the designer shall determine the appropriate barrier performance level based on a site-specific benefit-cost analysis. The performance level selected shall not be less than that required by these charts.

Figure B2: Curvature factor



B4 Barrier acceptance criteria

Only barriers that comply with one of the following criteria shall be used for side protection on structures:

- a. The barrier system is listed in NZTA M23⁽²⁾, ie has undergone satisfactory crash testing to the appropriate test level in accordance with NCHRP Report 350⁽⁶⁾ or higher, and has been accepted for installation in New Zealand.
- b. The barrier system is based on similar crash tested barriers used elsewhere subject to formal acceptance by the road controlling authority.
- c. The barrier system is a variation of B4(a) or B4(b) and has been 'deemed to comply' by the NZTA.

Crash testing/performance of the proposed barrier shall be to the appropriate level as determined in B3.

B5 Standard solutions

Table B2 gives standard non-proprietary solutions that meet the performance levels indicated. Equivalent lateral forces for each performance level are given in section B6 for design of the supporting structure and reinforcement for continuous rigid concrete barrier systems, where the profile has been accepted for the appropriate performance level. The standard solutions listed are not intended to be a complete list of acceptable solutions. The designer may specify alternative barrier systems subject to the acceptance criteria of section B4 and elsewhere in this manual.

Table B2: Standard non-proprietary solutions

Barrier performance level	NCHRP Report 350 ⁽⁶⁾ test level	Accepted barrier types	Reference
3	TL-3	W-beam guardrail (2.7mm thick, grade 350MPa steel), posts at 1.905m centres Rails may be added to this barrier to provide a combination barrier on non-state highways (see B6.6)	NZTA M23 ⁽²⁾ appendix B.
4	TL-4	a. Modified Thrie-beam with modified I section blockout and posts, posts at 2.0m centres, 865mm high Rails may be added to this barrier to provide a combination barrier (see B6.6) b. Monolithic 'F' shape concrete barrier 915mm high	AS/NZS 3845 ⁽⁹⁾ NZTA M23 ⁽²⁾ appendix B
5	TL-5	a. HT 'F' shape barrier. This is the TL-5 barrier preferred by the NZTA and may be used as a combination barrier (see B6.6) b. Monolithic 'F' shape concrete barrier 1070mm high	NZTA M23 ⁽²⁾ appendix B NZTA M23 ⁽²⁾ appendix B
6	TL-6	Any FHWA TL-6 approved system, subject to the road controlling authority's acceptance	FHWA website ⁽¹⁰⁾
SPECIAL	Requires specific design		

Note:

820 high VCB barrier to the profile shown in AS/NZS 3845⁽⁹⁾ figure 3.12(6) and with reinforcement determined using the equivalent lateral forces in B6, may be used on non-state highways where there is a permanent posted speed limit of 50km/h or less with the acceptance of the road controlling authority. The requirements for the occasional presence of people given in B2.9 should be noted.

B6 Side protection design criteria

B6.1 Equivalent lateral loads and height of application for rigid traffic barriers

Where a rigid barrier system other than those listed in NZTA M23⁽²⁾ is proposed, the loads in table B3 shall be used to determine structural requirements such as the reinforcement required in continuous rigid concrete barriers where the profile has been accepted for the appropriate performance level. These loads shall be treated as ultimate limit state loads and no further load factor need be applied to them. The transverse and longitudinal loads shall be applied at height H_e . The load F_v shall be applied along the top of the barrier as indicated in figure B3. All loads shall be applied to the longitudinal barrier elements.

Design of reinforcement for rigid concrete barriers using the loads in table B3 requires detailed analysis. Loads should be applied uniformly over the specified contact lengths. Design of rigid concrete barriers shall be carried out in accordance with 4.2 of this manual.

B6.2 Equivalent lateral loads and height of application for semi-rigid traffic barriers

Where a semi-rigid barrier system other than those listed in NZTA M23⁽²⁾ is proposed, the loads in table B4 shall be used to determine the structural requirements. These loads shall be treated as ultimate limit state loads and no further factor need be applied to them. The transverse (outward and inward) and longitudinal loads shall be applied at height H_e . All loads shall be applied to the barrier elements. In general the longitudinal load F_L will set the rail type and thickness required for the adopted barrier performance level. Construction of the adopted rail system shall ensure the full strength is available.

Where a semi-rigid barrier system is positioned on a single lane bridge then the transverse loads can be taken as 67% of those specified in table B4.

Semi-rigid barrier design shall assume use of a mechanical fuse to limit deck and superstructure loadings with the barrier system reliant on the longitudinal tension developing in the rail to provide errant vehicle re-direction. Rail anchorage requirements as set out in table B4 must be met to ensure the rail longitudinal tension develops. Barrier design must also ensure appropriate transitions are provided between the barrier on the structure and the connecting approach barrier.

Full capacity 'button head' high strength bolt fixings shall be provided at all rail to post and blockout connections. Quick release fixings shall not be used.

Table B4: Semi-rigid barrier design criteria (assuming the barrier has a minimum lateral offset to the deck edge of 0.5m)

Barrier performance level	Minimum transverse outward load ¹ F_{to} (kN)	Minimum transverse inward load ² F_{ti} (kN)	Number of posts fully loaded in the design collision ³	Expected longitudinal barrier load in the design collision ⁴ F_L (kN)	Minimum longitudinal barrier anchorage load ⁵ F_{LA} (kN)	Barrier centreline height ⁶ H_e (mm)
3	45	19	3	500	450	550
4	60	24	5	900	750	620

Notes:

1. Transverse outward load is to be applied to determine the post or its fixing fragility under the typical errant vehicle collision. The load level is set to optimise energy absorption and control ongoing collision maintenance.
2. Transverse inward load is to be applied to determine the post or its fixing fragility under an errant vehicle snagging collision. The load level is set to optimise energy absorption and control ongoing collision maintenance.
3. For ultimate limit state design of the supporting bridge deck and superstructure, retaining wall or foundation the specified number of posts shall be fully loaded for the transverse outward or inward loads for the case under consideration.
4. The minimum F_L specified shall be used to confirm rail longitudinal strength and minimum connectivity.
5. The minimum F_{LA} specified shall be provided to ensure the rail barrier re-directs the errant vehicle within the allowable lateral displacement. With the use of standard cross braced cable bays a nominal 150kN tension per bay is achieved, hence the minimum anchorage specified is equivalent to 3 bays and 5 bays respectively for the two barrier performance levels. Barrier rail anchorage set out shall meet the layout detailed in NZTA M23⁽²⁾ appendix B for non-proprietary systems. In general the typical anchor spacing on straight structures shall not exceed 80m. For curved structures (>250m radius) the anchor spacing along the outside edge of the curve may be set at 100m whereas the anchor spacing along the inside edge of the curve shall not exceed 60m. Anchor spacing for structures on small radius curves shall be subject to specific design.
6. The barrier transverse and longitudinal loads shall be applied at the specified barrier centreline height, as measured from the top of the road surface at the face of the barrier. Barrier set out shall include allowance for the road surfacing strategy at the site.

B6.3 Design of deck slabs and retaining walls to resist barrier forces

Design of a deck slab shall be such that any failure is confined to the barrier and that the fixings to the deck, the deck slab and supporting structure are not damaged during failure of the barrier, except where holding down bolts are specifically designed to break away in semi-rigid barrier applications or starter bars are designed to yield for rigid barriers.

The design of a retaining wall where a barrier is on top shall be similarly undertaken such that failure is confined to the barrier. Load distribution from the barrier into the retaining wall, either integral with the retaining wall or with separate foundations at the top of the retaining wall, may be considered in accordance with figure 6 of *Design criteria of standard earth retaining systems*⁽¹¹⁾.

- a. For rigid barrier systems, the equivalent ultimate limit state forces and contact lengths set out in table B3 shall be used for the calculation of forces in the deck, retaining wall or foundation for the required performance level. The deck, wall or foundation capacity shall be sufficient to resist overstrength actions generated by the barrier capacity, when the loads set out in table B3 are applied. Characteristic strengths and capacity reduction factors of $\phi=1.0$ for flexure and $\phi=0.85$ for shear shall be used for the design of the deck, wall or foundation capacity.

When barrier collision occurs the overstrength capacity collision load actions shall be combined with an HN vehicle positioned at the barrier face. This vehicle load may be considered as an overload (OL) for the determination of load factors.

- b. For semi-rigid barrier systems, the deck slab, retaining wall or foundation shall be designed to withstand the forces mobilised by the yielding components of the barrier post (ie either the post fixings or post base acting in flexure or shear) developing their overstrength capacity.

Deck slab and foundation design shall consider two collision load cases, whilst retaining wall design need only consider the first collision load case:

- i. When barrier collision just occurs the post or base plate overstrength capacity collision load actions shall be combined with an HN vehicle positioned at the rail barrier face.
- ii. After barrier collision when the HN vehicle shall be positioned at the deck or foundation edge to generate the most adverse actions. It is assumed the barrier has 'knocked-off' and no collision load need be applied in this case.

In both instances the vehicle load may be considered as an overload (OL) for the determination of load factors.

B6.4 Pedestrian, cyclist and equestrian barriers

Pedestrian, cyclist and equestrian barriers shall be designed for the most extreme of the following loads:

- a. horizontal and vertical service loads of 1.75kN/m applied to the top rail
- b. a horizontal service load of 1.5kN/m² applied to the gross area of the barrier
- c. a point load of 0.5kN in any direction at any point.

Horizontal and vertical loads need not act concurrently.

In addition to the provisions above, where the road controlling authority requires the barrier to restrain crowds or people under panic conditions, the barrier shall be designed for the most extreme of the following loads:

- a. a horizontal service load of 3.0kN/m acting away from the path simultaneously with a vertical service load of 0.75kN/m acting on the top rail

B6.4 continued

- b. a horizontal service load of 1.5kN/m simultaneously with a vertical service load of 0.75kN/m acting on any one longitudinal member
- c. a horizontal service load of 1.5kN/m² applied to the gross area of the barrier
- d. a horizontal point load of 1.0kN acting away from the path at any point.

The load factor for the ultimate limit state shall be 1.8 for design of the barrier, fixings and supporting structure.

Note that for cyclist and equestrian barriers the loads to the top rails are applied at a height greater than the maximum required under *New Zealand building code* verification method B1/VM1⁽¹²⁾.

Consideration shall be given to the provision of a separate handrail in situations where clause D1 *Access routes* of the *Building code*⁽³⁾ is applicable.

The barrier shall present a smooth surface without snagging points. A fundamental principle in designing barrier protection for cyclists is that the first point of contact between a cyclist and the barrier should be the cyclist's forearm with the barrier top rail.

Pedestrian, cyclist and equestrian barriers shall also satisfy the following criteria:

- a. Rails shall be round or possess round corners to minimise the potential for injury to users of the structure, particularly cyclists, toppling into them.
- b. Supports shall be installed to minimise the potential for snagging of cycle handlebars or pedals. The *Austrroads Guide to road design* part 6A *Pedestrian and cyclist paths*⁽¹³⁾, indicates there should be a 150mm pedal clearance from top rail to post on full barriers.
- c. They shall extend sufficiently beyond the ends of the structure to satisfy the requirements of the *Building code*⁽³⁾.

B6.5 Equestrian barriers

Not used. See B2.5 and B6.4.

B6.6 Combination barriers (traffic and pedestrian/cyclist/equestrian)

Combination barriers shall be designed to resist the forces appropriate to the barrier performance level required from B6.1 or B6.2. Pedestrian/ cyclist portions of combination barriers shall resist loads of 4.4kN/m horizontally and 1.75kN/m vertically, applied to the top rail. Other members shall resist, as a minimum, the loads described in B6.4. The load factor for these pedestrian/cyclist loads for the ultimate limit state shall be 1.8.

Rails to combination barriers shall also satisfy the following criteria:

- Rails shall be round or possess round corners to minimise the potential for injury to cyclists toppling into them.
- Supports for the rails shall be installed to minimise the potential for the snagging of cycle handlebars.
- Barrier rails shall be positively interconnected at expansion joints in the rails with a connection of sufficient strength to prevent the rails separating under vehicle impact and spearing the impacting vehicle. The capacity of the rail-barrier connection shall be sufficient to support the rail from collapsing off the structure following an impact.
- Rails shall extend sufficiently beyond the ends of the structure to satisfy the requirements of the *Building code*⁽³⁾ and then be deflected downwards and anchored.
- Intermediate rails shall be provided such that any clear gaps between rails and barrier comply with the *New Zealand building code* acceptable solution F4/AS1⁽⁴⁾.

B6.6 continued

- Whilst, for the safety of cyclists, the minimum height to the top edge of the top rail is generally 1400mm, the use of an HT 'F' shape barrier (1270mm high), as detailed in table B2, is generally considered acceptable for cyclist protection. An exception to this is when the cyclists are accommodated on a path outside of the barrier, when an additional top rail on the path side of the barrier may be provided at 1400mm height.
- Systems that have not undergone crash testing require acceptance from the road controlling authority as a deemed to comply system.
- The front face of the rails shall be set back from the vertical plane of the barrier face to minimise vehicle impact on the rails, unless the rail is a structural element of the barrier system.
- The design of any top rails to a concrete barrier, including the fixings, shall ensure that the rail system fails in a ductile manner.

B6.7 Debris screening

Debris screening shall be incorporated into side protection barriers on structures where debris falling through such barriers could create a hazard to motorists on adjacent carriageways or carriageways beneath the structure or to adjacent land users.

Where debris screening is required for a structure carrying traffic over another carriageway or running immediately adjacent to, and at a higher level than, another carriageway, the edge protection system used shall provide a solid screen to a minimum height of 400mm above the higher carriageway to prevent debris falling onto the carriageway below.

If this screen is not provided by the side protection system itself, then a separate screen shall be provided on the external face of the barrier to satisfy this requirement.

Similarly, where debris screening is required for a structure carrying pedestrians or cyclists over a highway, a solid screen to a minimum height of 100mm above the path shall be provided. A kerb will satisfy this requirement.

Consideration must also be given to the provision of anti-throw screening to prevent objects being thrown onto the carriageway below, in particular bridges with provision for pedestrians over urban motorways. This should be done on an exposure/outcome basis and take into account the composition of the bridge users and the obstacle being spanned.

Where anti-throw screens are required they shall meet the minimum provisions of AS 5100.1⁽⁸⁾ clause 12.3.

B7 Geometric layout, end treatment and transitions - the NZTA's requirements

B7.1 General

Accepted barrier systems, end terminals and transitions are detailed in NZTA M23⁽²⁾ and the accompanying appendices.

B7.2 Rigid barrier

Rigid barriers shall generally be orientated vertically in the transverse direction. If the crossfall is less than 5% it may be more appropriate to rotate the barrier so that its axis is perpendicular to the road surface, as shown in figure 6.17 of the Austroads *Guide to road design* part 6⁽¹⁾.

B7.3 Semi-rigid barrier

Installation of proprietary semi-rigid barrier systems shall be in accordance with the manufacturer's instructions for the performance level prescribed.

B7.3 continued	<p>Unless specified otherwise in manufacturer's instructions or NZTA M23⁽²⁾, posts shall be erected normal to the road surface in the longitudinal direction, but vertical in the transverse direction.</p> <p>Holding down bolts shall be specifically designed to be easily removed and replaced after failure or damage.</p>
B7.4 Structure approaches	<p>The protection level provided by the barrier on the approaches to the structure shall be appropriate for the hazard at the structure. Where the protection level on the approach is less than that provided on the structure, the length of approach transition shall be assessed as the appropriate length of need for the hazard (<i>Austroads Guide to road design</i> part 6⁽¹⁾).</p> <p>A smooth continuous tensile face shall be maintained along the transition. Any exposed rail ends, posts or sharp changes in barrier component geometry shall be avoided, or sloped outwards or downwards with a minimum flare of 1 in 30 for barrier components and kerb discontinuities.</p> <p>Standard transition details are given in NZTA M23⁽²⁾ appendix A. Flexible (wire rope) barrier systems are not acceptable for edge protection on structure approaches as these are difficult to transition to semi-rigid and rigid systems.</p>
B7.5 End treatment	<p>The ends of a barrier shall have a crashworthy configuration or be shielded by a crashworthy barrier or impact attenuation device.</p> <p>Acceptable end terminals are detailed in NZTA M23⁽²⁾ appendix A.</p>
B7.6 Kerb	<p>Notwithstanding the requirement to maintain the approach road cross-section across the bridge, where the width between approach kerbs is different from that on the bridge, the horizontal transition between the two shall be an 'S-curve' such that the overall taper rate (rate of lateral shift) is not less than 0.6m/s of travel time at the design speed.</p> <p>For example; a 300mm change in width in a 50km/h speed environment would transition over a distance of $0.3 \times 13.9 / 0.6 = 7.0\text{m}$.</p> <p>Where the profile of the kerb on the bridge differs from that on the approach the transition between the approach kerb profile and that over the bridge should occur over a distance of between 2m and 5m (depending upon the extent of the change) and must not present an opportunity to either snag or launch an errant vehicle.</p>
B7.7 Barrier layout	<p>The geometric layout for the barrier on the approach to single and two-lane bridges shall comprise the appropriate performance level for the length of need required to protect the hazard, together with the appropriate transition sections between barriers of different test levels. The length of need shall be calculated in accordance with the <i>Austroads Guide to road design</i> part 6⁽¹⁾. (An example calculation is given in appendix I of the guide.) In New Zealand, the 'Angle of departure' method is preferred.</p>

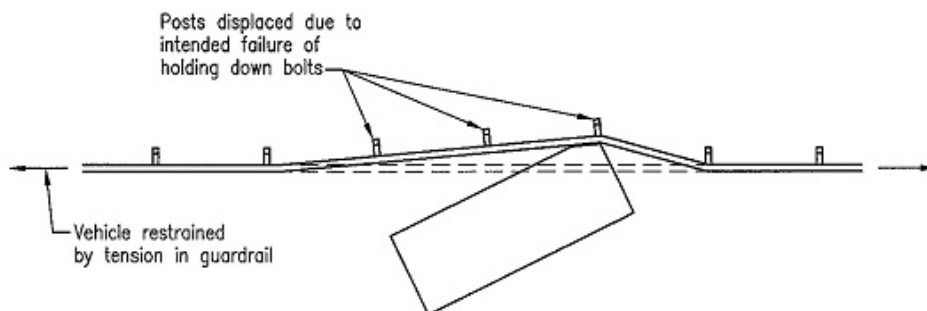
B8 Non-proprietary bridge barrier system

B8.1 General

Details of a non-proprietary semi-rigid bridge barrier system that is suitable for use on state highway bridges, are given in NZTA M23⁽²⁾ appendix B.

The principle of operation of this system is shown in figure B4. It should be noted that, in this design, the use of holding down bolts with a specific minimum and maximum strength is essential. Deck slab details near to barrier posts for this system are shown in figure B5.

Figure B4: Semi-rigid barrier displacement and local post failure at impact



B8.2 Length changes and anchorages

a. Bridge length changes

No free longitudinal movement shall take place in joints between lengths of guardrail.

The guardrail is assumed to be fixed in space between its end anchors, while the bridge deck (and the guardrail posts) move relative to the guardrail as a result of temperature, shrinkage and creep effects. Provision shall be made in the guardrail at each post connection to enable relative movement to occur at this location. It is also assumed that longitudinal forces due to temperature changes can be resisted by the guardrail. Guardrail expansion joints shall be used only on bridges where long lengths of continuous superstructure between deck expansion joints give length changes that cannot be accommodated within the normal post expansion provision. Where the distance from a guardrail anchor point to the nearest deck expansion joint, exceeds 100m then an expansion joint is to be provided in the guardrail itself.

The expansion joint shall enable slow movements to take place without restraint, but act as a rigid connection under impact loading. Expansion joints or other devices which use rubber components to absorb movement shall not be used.

b. Guardrail anchors

Unless linked to highway guardrails on the approaches, a bridge guardrail shall be provided with end anchors capable of resisting its specified ultimate load. A bridge guardrail more than 150m long shall be provided with intermediate anchors as described below, capable of resisting the same load. The following types of anchors shall be used in the situations described:

i. Buried anchor

Where the approach to a bridge is in soft rock or a soil cutting the anchor to an approach guardrail should, if possible, be buried. Soil covering the anchor shall be well compacted. Details of a standard NZTA buried anchor are shown in NZTA M23⁽²⁾ appendix A.

B8.2 continued

ii. End treatment

Refer to B7.5.

iii. Intermediate anchor on a bridge

The anchor posts shall be designed to break away from the deck at their bases in the event of direct vehicle impact. When this occurs, restraint of the guardrail ribbon is provided by the adjacent anchors.

Details of a standard NZTA intermediate anchor are shown in NZTA M23⁽²⁾ appendix B.

c. Location of anchors

Guardrail anchor location requirements are as follows (they are shown diagrammatically in figure B6):

- The maximum distance between adjacent anchors shall be 150m.
- The maximum length over three consecutive anchors shall be 200m.
- Intermediate anchors shall be located at neutral points. Neutral points are defined as points on the bridge length which do not move longitudinally with length changes. If this is not possible, due to location of two or more anchors between consecutive expansion joints, the effect of the movement of the anchors relative to the guardrail due to creep and shrinkage shall be taken into account in the design by providing for adjustments in the anchor cable connections.
- If there is a high proportion of very heavy traffic and/or severe curvature, consideration should be given to providing guardrail anchors at every neutral point.
- End anchors shall be located at the appropriate distance from the bridge abutment or ends of a structure to satisfy the length of need required to protect the hazard.

Figure B5: Non-proprietary bridge barrier system – deck slab details near guardrail posts

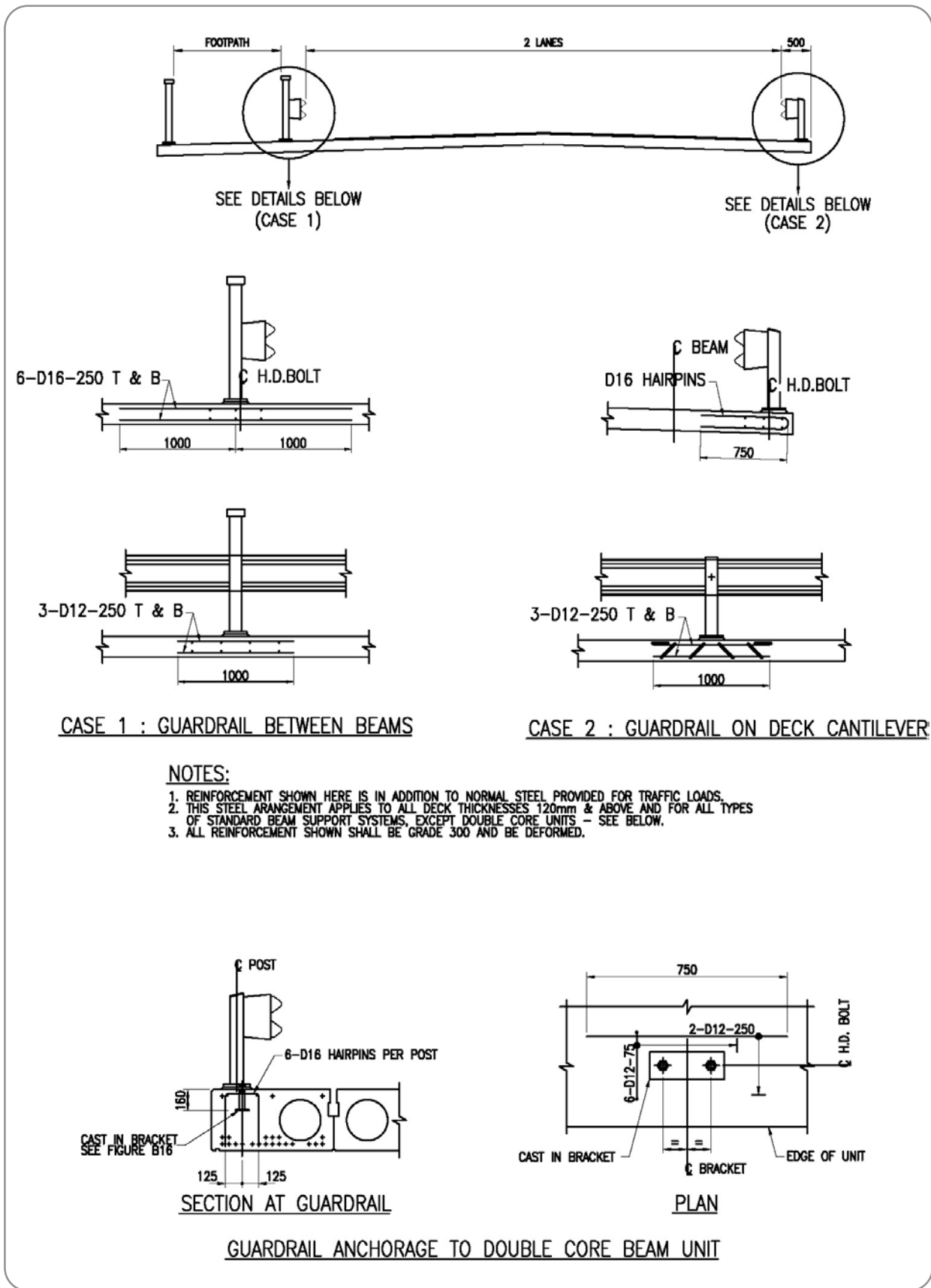
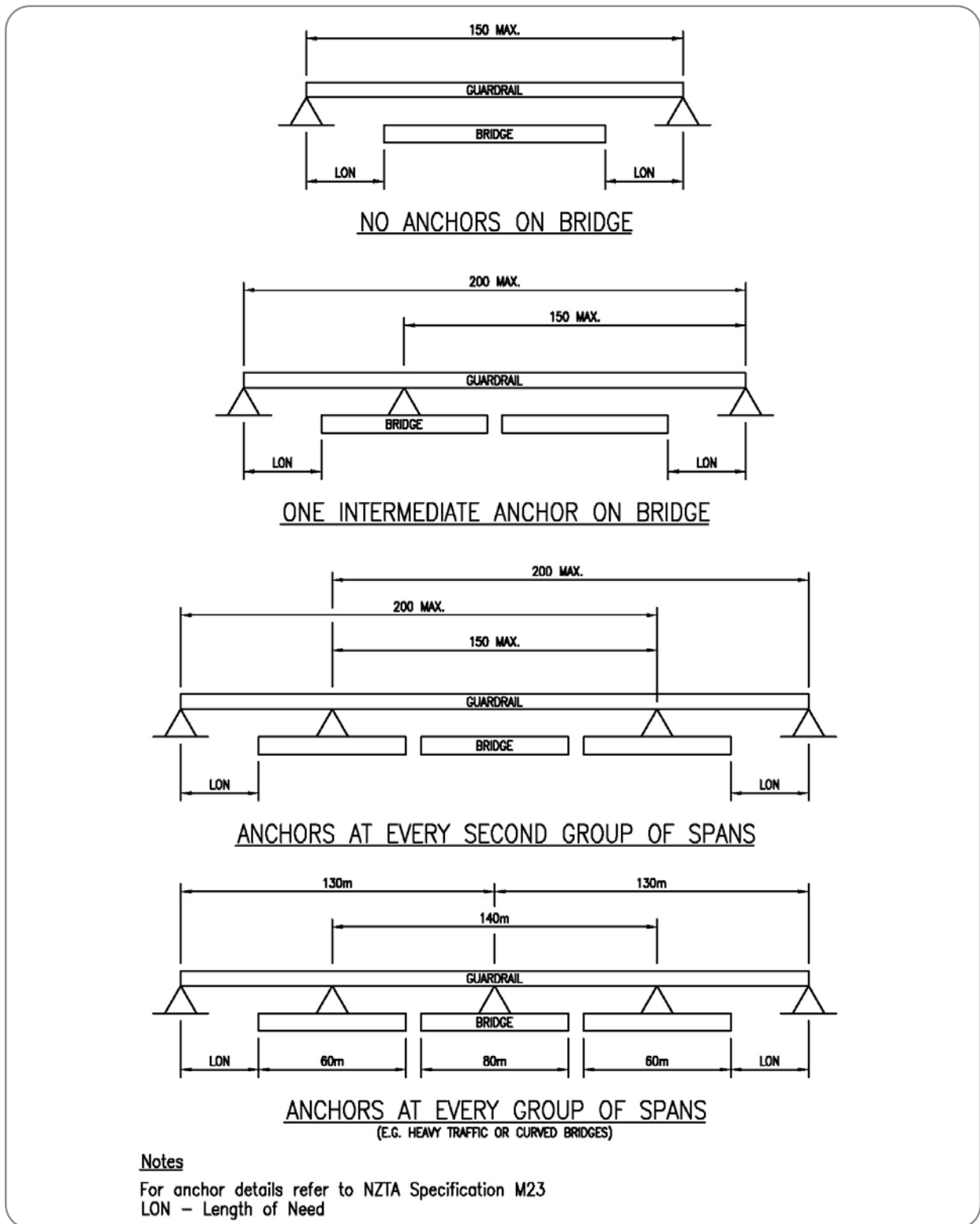


Figure B6: Non-proprietary bridge barrier system - anchor locations



B9 References

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 - (2) NZ Transport Agency (2009) *NZTA M23 Specification for road safety barrier systems*. Wellington.
 - (3) Parliamentary Counsel Office (1992) *Building Regulations 1992*. Schedule 1 *The building code*. Wellington.
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 - (6) National Cooperative Highway Research Program (1993) *Recommended procedures for the safety performance evaluation of highway features*. Report 350, National Academy Press, Washington DC, USA.
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 - (11) California Department of Transportation (2014) *Design criteria of standard earth retaining systems*. Memo to designers 5-5, Sacramento, CA, USA.
 - (12) Ministry of Business, Innovation & Employment (2014) *Acceptable solutions and verification methods for New Zealand building code clause B1 Structure*. Wellington.
 - (13) Austroads (2009) *Guide to road design*. Part 6A Pedestrian and cyclist paths, AGRD06A-09. Sydney, NSW, Australia.
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