# Crash Barrier on Reinforced Earth Wall – Liverpool Parramatta Transitway

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**SYNOPSIS**

Reinforced earth walls are increasing being utilised for economic and aesthetic reasons as earth retaining structures on and around road traffic installations. Abigroup, the contractor for the Liverpool Parramatta Bus Transitway project based their successful tender on the use of reinforced earth for the retaining walls in the elevated sections of the transitway with continuous slip formed concrete crash barriers.

Reinforced earth walls are often a very competitive solution for earth retaining structures, but when crash barriers have to be placed on top of them, it is difficult to carry the crash load forces back into the reinforced earth.

A solution was required by Abigroup Contractors to comply with the specified barrier impact loadings without overloading the reinforced earth wall, while at the same time minimising the barrier concrete foundation costs.

This paper shows how an economical and effective solution was achieved using designs to isolate the crash barrier lateral impact loads from the reinforced earth retaining walls and the method of allowing for thermal and shrinkage effects along the long slip-formed concrete barriers.

## 1 INTRODUCTION

The RTA of NSW called tenders in 2002 for design and construction of the Liverpool Parramatta Bus Transitway, which is located within the main Sydney water supply pipe easement. The Transitway consists of two bus traffic lanes totalling 8.2 metres between kerbs which had to fit within the limited width available in the easement.

The grades in the easement necessitated that several kilometres of the Transitway be elevated, requiring two retaining walls to contain the fill, road base and traffic loads (see Figure 1). Heights retained were generally 2 to 3 metres above natural ground level, with some sections up to 6.5 metres above ground level. On the pipeline side of the alignment a sight screen to block views of the pipe is erected on top of this barrier. The screen height is specified as 2.5 metres above the roadway, with provision for extending to 3.0 metres in the future. For other substantial lengths the Transitway is in cut down to approximately 800 mm deep, with the remainder of the Transitway at ground level.

Crash barriers had to be provided along both sides of the Transitway not only to protect the buses, but also to minimize the risk of damage to the pipes running parallel to the Transitway, which are crucial to Sydney's water supply.

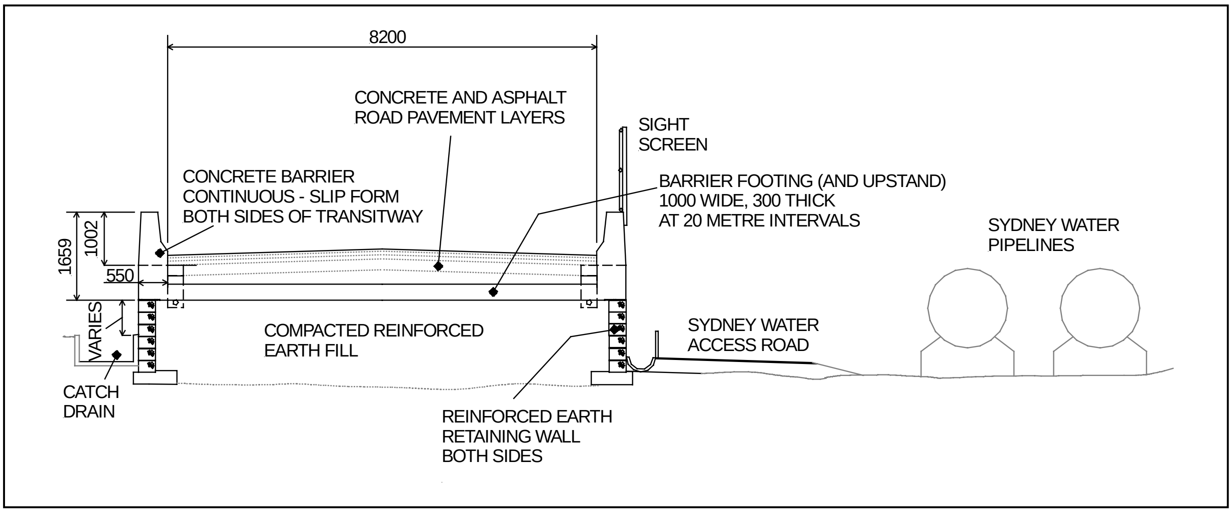


***Figure 1: Cross Section at Footing, Liverpool Parramatta Bus Transitway***

The successful tender submitted by Abigroup Contractors was based on the use of reinforced earth retaining walls for the elevated sections of the Transitway as well as the use of slip-formed concrete crash barriers on continuous concrete footings under the pavement.

The Road Traffic Authority of NSW specified that this Transitway use Level 2 Barrier Design Loads and Concrete Safety Shape barriers in accordance with the current Austroads Code (1). Level 2 Barriers must be designed to resist an ultimate design transverse force of 90 kN applied at any point on the barrier.

It is preferable not to design reinforced earth retaining walls to carry the barrier horizontal impact design loads, because as a locally added direct horizontal force, the number of reinforced straps will be considerably increased, and there will still need to be a system for carrying the overturning moments.

The paper shows how the design of the barrier and footings was achieved allowing for impact and wind load conditions, plus the thermal and shrinkage effects on continuous barriers, and how the lateral loads and overturning moments were isolated from the reinforced earth structure. This design, resulting in a significant reduction in the concrete volumes for the barrier footings, together with the Contractor's methods of slip-forming the concrete barrier, and the use of reinforced earth for the retaining walls, produced an economical and effective solution.

## 2 DESIGN

The design and construct solution chosen was to provide a series of isolated footings across the full width of the roadway to transfer the barrier impact loads to the earth fill across the roadway, and to design the crash barrier to span laterally between these footings for the transverse impact load. The self weight of the barrier is supported vertically by the reinforced earth wall, which it can easily do.

### 2.1 Concept

The structural arrangement of the barrier as a laterally spanning beam is to carry to the isolated impact load along the barrier to expansion joints situated at 3.5 metres each side of the centrelines of isolated footings, which are at 20 metre intervals (see Figure 2). These expansion joints can carry shear and torsion loads across them, but not bending moments. The shear loads are then carried in lateral cantilever action along the 3.5 metre section of barrier between the expansion joint and the footing. The vehicle impact above the concrete barrier shear centre is carried in beam torsion action, as are the wind loads from the sight screen. These loads are carried from any point along the barrier back to the footing, through the expansion joint.

For the 95% of the reinforced soil structure between the footings, the reinforced earth retaining structure needed to be designed only for normal vertical vehicle loads, superimposed dead loads and soil pressures.

For locations of the concrete barriers other than on the reinforced earth retaining walls, the same foundations as for the elevated locations were suitable. Alternative designs were also provided to the Contractor for pairs of isolated footings outside each side of the alignment, instead of one footing locally across the alignment. These alternative footings are not discussed in this paper.

### 2.2 Design Parameters

The loads and conditions in the design are:

- Vehicle: The Austroads Code (1) Level 2 barrier requires a vehicle impact loading of 90 kN Ultimate which can be applied at an isolated location at any point on the barrier. This impact load is distributed over a longitudinal distance of 1.5 metres and then at 45 degrees down to the supporting slab or foundations. An ultimate load factor of 2.0 is incorporated in this figure. No other design vehicle loads are applied to the crash barriers or their footings.

- Wind Loads: Derived from SAA Loading Code Part 2 Wind Loads (2) for the terrain, the height above ground and the location of the Liverpool Parramatta Transitway

The vehicle impact loads and wind loads are not required to be applied simultaneously under the Austroads Code (1). The final design was based on limiting the foundation bearing pressures beneath the reinforced earth wall as required by the designers of the reinforced earth structure.

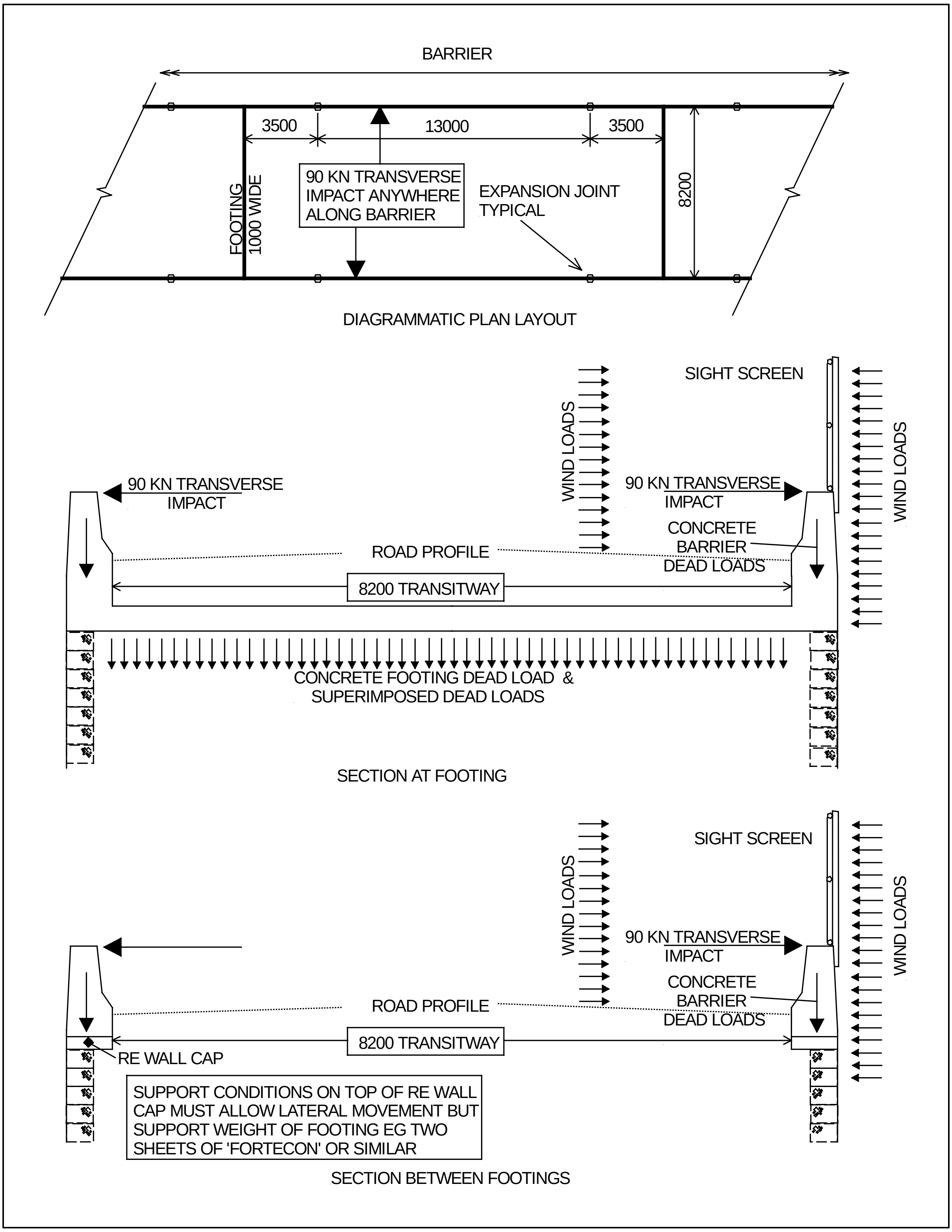


***Figure 2: Application of Loads to Integrated Barrier and Footing Structure***

## 2.3 Barrier

A torsion flexure line beam model was used for the barrier design to simulate a beam spanning horizontally between cantilevers to isolated footings (see Figure 3). A range of span lengths was investigated with the aim of maximising the span between the isolated footings. The 20 metre span finally adopted proved to be the limit of this solution both for the reinforcing required in the barrier for the bending, shear and torsion combinations as well as the limiting factor for the foundation contact pressures due to the vehicle impact conditions. The governing condition was the vehicle impact, not the wind load.

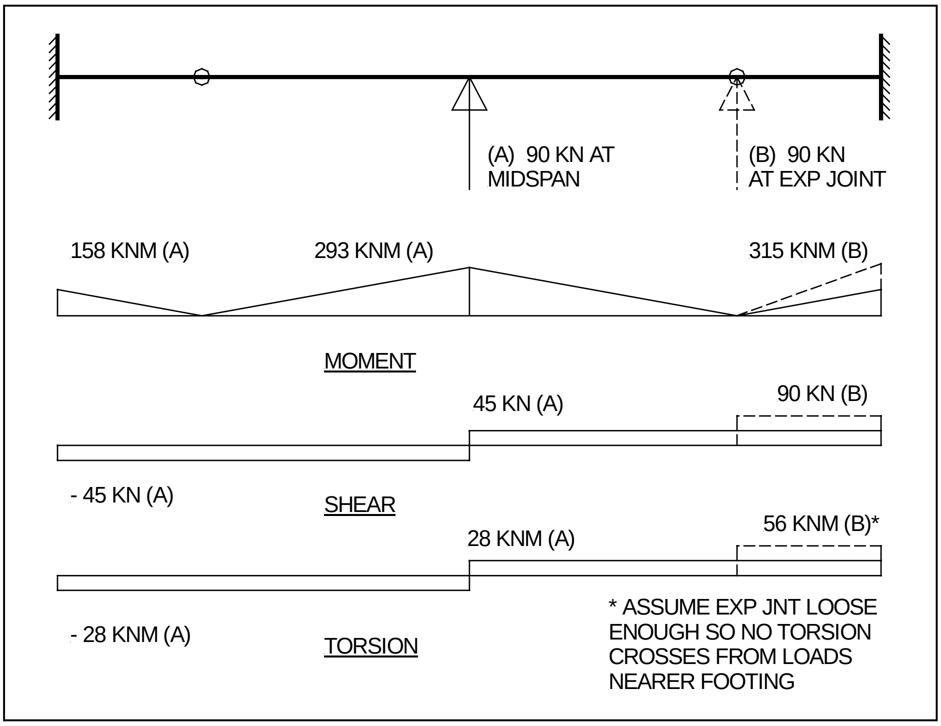


***Figure 3: Analytical Model and Results***

The torsion imposed on the barrier due to the transverse impact is significant along the length of the barrier beam for the various load conditions, as the impact is transferred by torsion (as well as flexure and shear) back to the isolated supports. This results in significant torsion reinforcement being necessary in this barrier, which would not be the case for a conventional concrete safety barrier on a continuous footing.

The barrier flexural reinforcement and the shear and torsion reinforcement in the final design approximate to 130kg per cubic metre of concrete for the barrier alone. This compares with reinforcing quantities of the order of 60 to 90kg per cubic metre for a typical standard concrete safety barrier to the current Austroads Code (1). The main reinforcing requirements and the locations of expansion joints in the final design are shown in Figure 4.

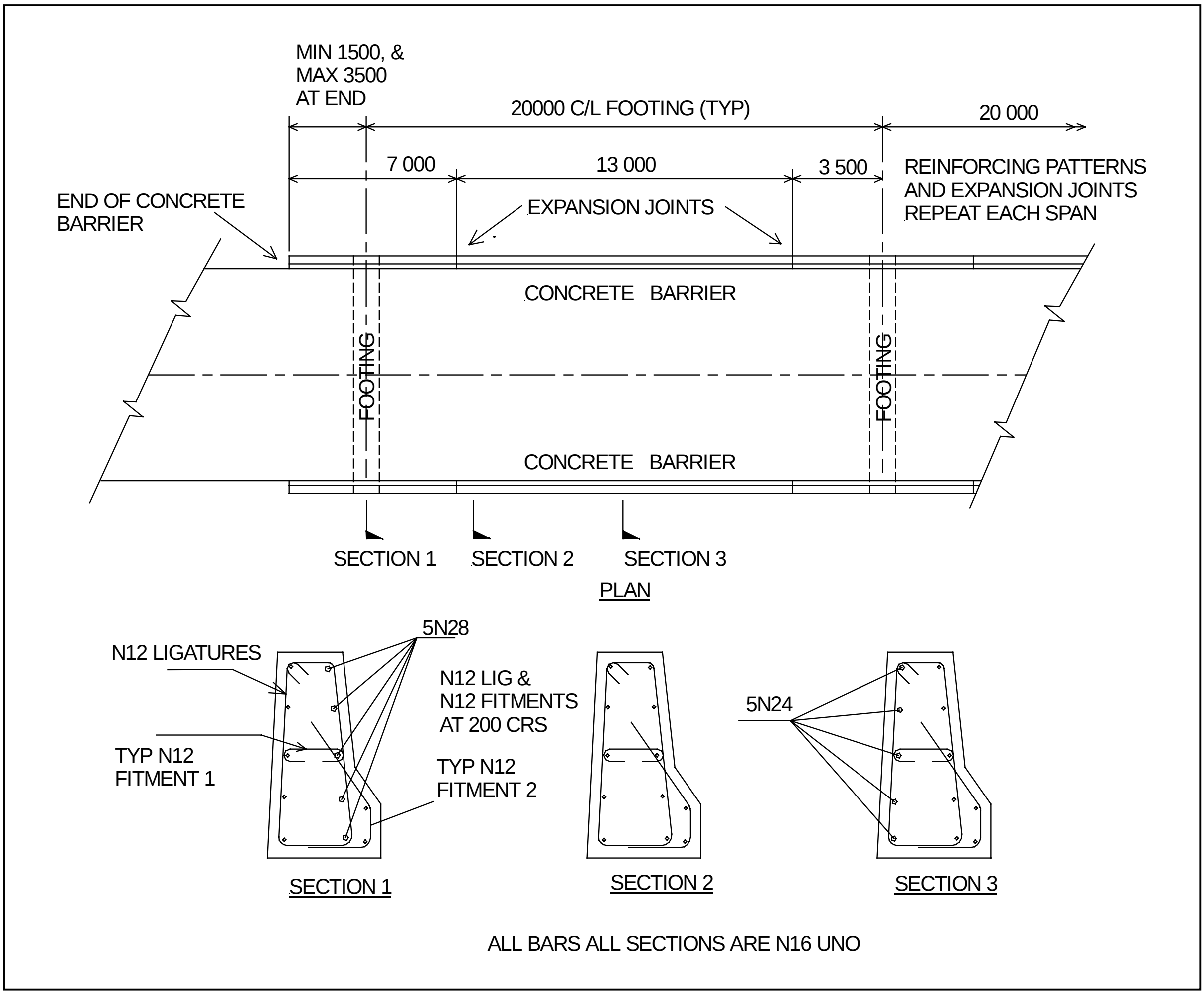


*Figure 4: Barrier Reinforcing Details - Liverpool Parramatta Bus Transitway*

## 2.4 Footings

At each footing, the lateral force and torsion loads from the vehicle impact and wind loads become sliding and overturning loads applied at the "wall" projecting above the footing. There is also a torsion load applied to this "wall" as the barrier loads twist it about its vertical axis because of the moment restraint in that direction. These loads are represented diagrammatically in Figure 5.

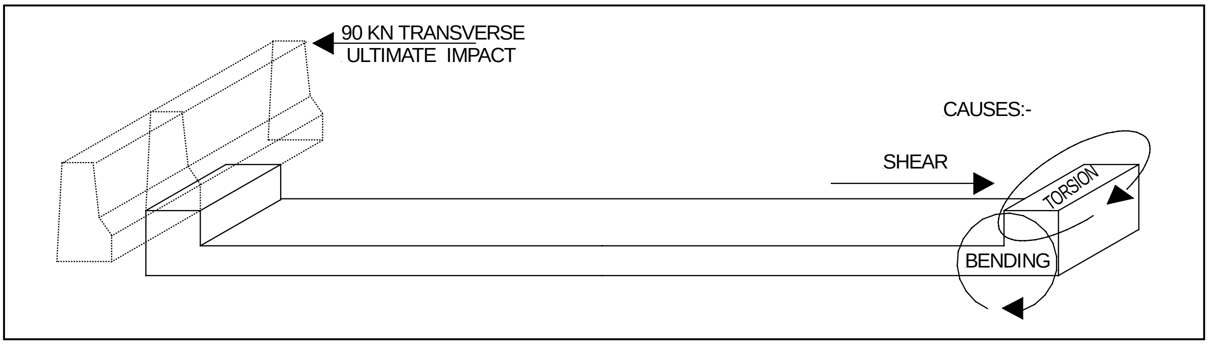


*Figure 5: Diagrammatic Isolated Footing Loads for Impact Barrier*

The final slab footing design is a one metre wide footing at twenty metre intervals, utilising the full width of the transitway for these isolated barrier foundations. This provides a suitable factor of safety against overturning under impact or wind load conditions, as well as keeping the soil bearing pressures and RE wall loads within allowable limits. There is no suitable provision in the Austroads Code (1) for design of shear and torsion interfaces like those between the barrier and the upstand, and the upstand and the footing. Therefore for these interfaces, the shear friction approach of the ACI Code (3) was used. For a relatively recent technical explanation of this see Mattock (4).

The following Figure 6 shows the main reinforcing for the final footing design.

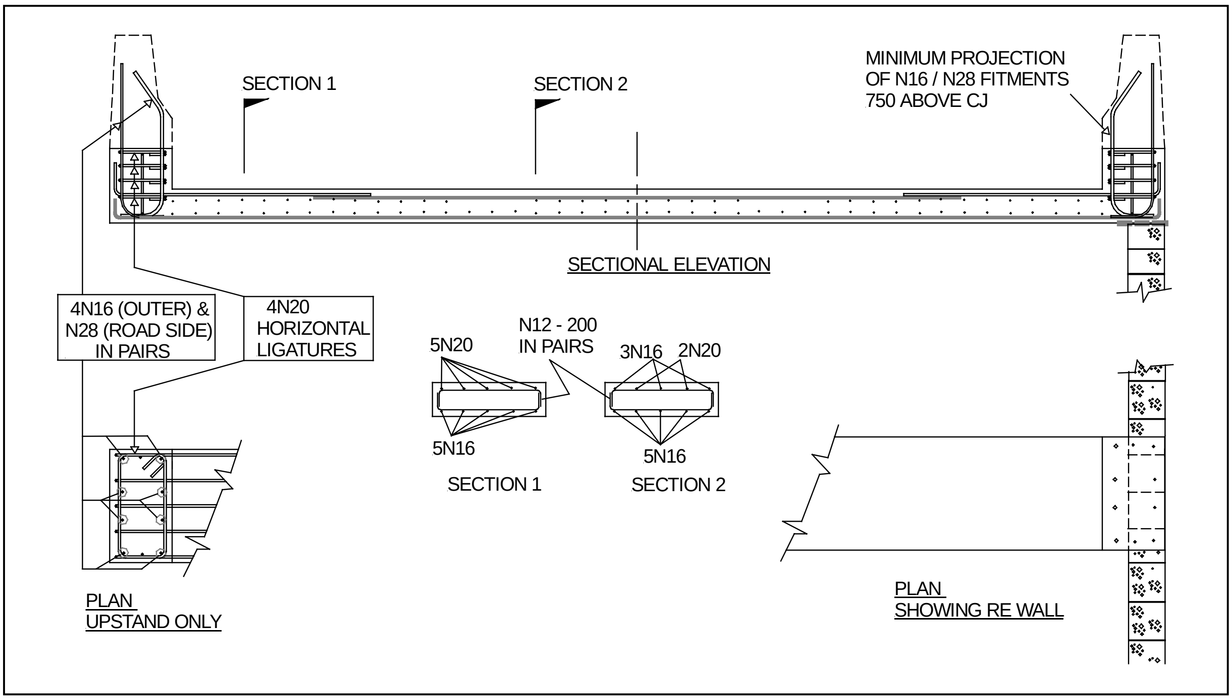


***Figure 6: Footing Reinforcing Liverpool Parramatta Bus Transitway***

## 2.5 Expansion Joints

Pairs of expansion joints are installed within each barrier between footings as shown in Figures 2 and 4 above. Thus there is a 13 metre barrier segment centrally located within the 20 metres between footings. The expansion joints have been designed, as described below to carry shear and torsion across the joint, but be axially released, and released for bending. The 13 metre barrier centre segment is a simple span in flexure between the 3.5 metre segments which cantilever back to the isolated footing upstands. However for loads within this 13 metre zone, the torsion span of the barrier is the full 20 metres. It has also been conservatively assumed that the expansion joint is sufficiently loose such that loads applied within the 3.5 metre distance between expansion joint and support will send all torsional load back to the support ie only torsional loads applied within the 13 metre zone will be carried across the expansion joint.

These expansion joints have two functions:

- They allow for the expected movement in the barrier due to thermal and shrinkage effects required by the Austroads Code (1)

- They ensure activation of the bond breaker between the barrier and the RE wall cap (see Figure 2). The axial thermal and shrinkage movements between these points will break any bond before an impact occurs ensuring very low forces laterally across the top of the RE wall.

The expansion joints are designed as 'torsion keys' using round bars which are able to slide in a socket on one side of the joint and are fixed on the other. The bars are sized to carry the shear at this location and are designed to carry the torsion utilising the lever arm between the upper two bars and the lower bar. The socket depth is determined by allowing sufficient length to take the forces in bearing resistance of the concrete. Concrete in the location of the stress bars is reinforced for lateral suspension to ensure loads are applied to the full lateral concrete depth as shown in the following Figure 7.

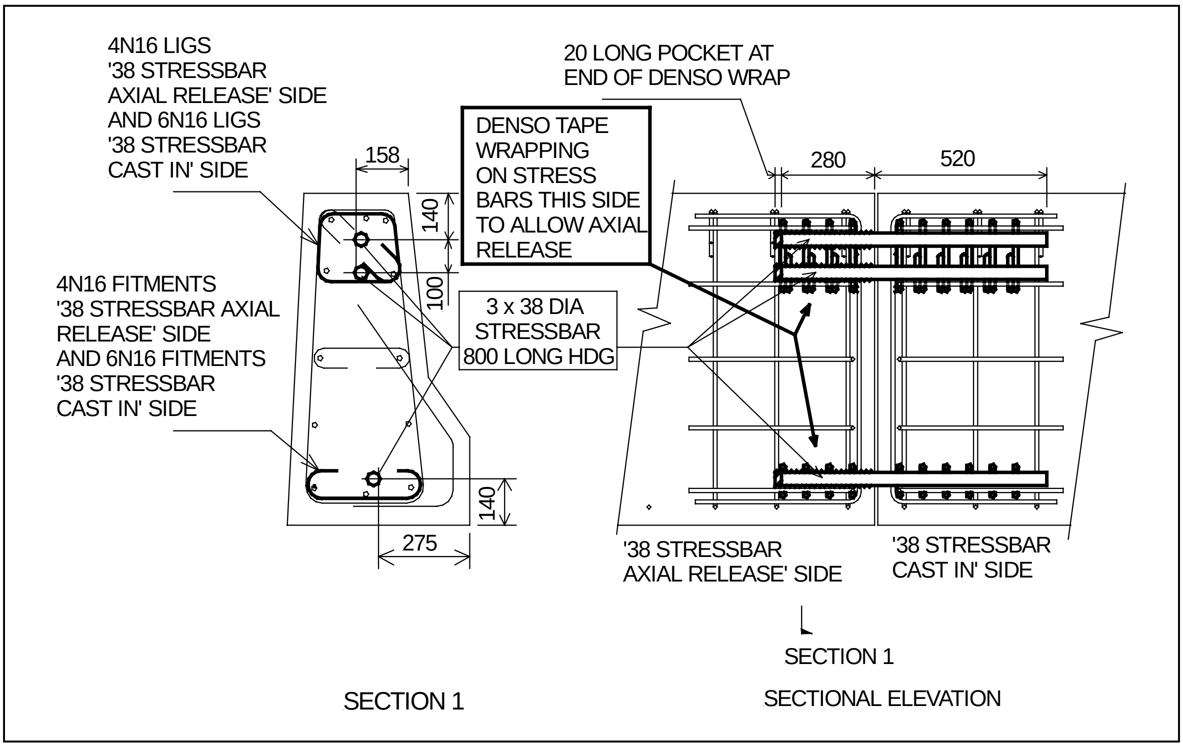


*Figure 7: Barrier Expansion Joint - Liverpool Parramatta Bus Transitway*

## 3 COMPARISON WITH CONVENTIONAL APPROACH

The final design described in this paper produced a solution for a slipformed continuous barrier supported at 20 metre intervals on isolated footings, which can be installed on top of a reinforced earth retaining structure. There are a number of interesting points of comparison between this and a more conventional solution utilising a continuous footing:

- The volume of concrete in this solution for the barriers plus footings is approximately 1000 cubic metres of concrete per kilometre of roadway, compared with the conventional solution volume in excess of 2000 cubic metres per kilometre. This is a considerable saving in a project of this size.

- The conventional solution places the horizontal lateral loads into the reinforced earth straps at all points along the alignment. This solution concentrates it at isolated locations occupying only 5% of the length of the alignment and disperses it back across the whole width of the alignment at those locations.

- The reduction or elimination of the horizontal force between the footings is also ensured by the axial thermal and shrinkage action between the expansion joints, causing the debonding desirable for lateral loads.

- The detailing of the RE wall and the isolated footings and upstands allows continuous slipforming of the barrier, leading to large cost and time savings.

- The reinforcing quantity for this barrier in this paper is approximately 130 kg/cubic metre compared to 60 to 90 kg/cubic metre for a conventional barrier, but this is more than offset by the reduced total quantities of reinforcement for the footings.

## 4 CONCLUSIONS AND FUTURE DIRECTIONS

A design solution has been developed which carries the vehicle crash impact loads by using the concrete safety barrier as a longitudinal beam. This beam sends the loads via torsion and flexure back to isolated footings which span the full width of the reinforced earth retaining structure. The design provides an economical solution with considerable construction advantages.

The current Austroads Code (1) Level 2 ultimate design transverse impact load is set at 90 kN applied over 1.5 metres, for standard height barriers. The authors understand that Austroads is currently considering adoption of much larger barrier loads, as proposed by Colosimo (5). These lateral loads range from 125 kN over 1.1 metres (“Low”) to 1000kN over 2.5 metres (“High”). These much larger ultimate impact forces would make it difficult to impossible to use the barrier design which is the subject of this paper. However it is even harder to see how such loads could be carried by a strip footing on a reinforced earth wall. For a case like the Liverpool Parramatta Transitway these large barrier loads would cause huge increases in cost, and the authors are not aware that any evidence is available to justify their adoption.

Alternative traffic safety barriers on bridges and elevated transitways should be the subject of detailed review and research by the Road Authorities to allow barriers which cater for the range of impact levels that may be experienced, including the more numerous cars and small vehicle fleet as well as the larger truck traffic. It is suggested that this review should cover aspects such as :-

(i) 'Softer' impacts.
(ii) Better vision.
(iii) Economical construction.

Wire rope barriers are now widely used on roads (see Reference 6), and meet all these criteria, but require significant lateral deflection distance. They could possibly be developed for use on bridges and elevated roadways. The problem is that the lateral distance required for vehicle containment is up to 1.5 metres for cars and more for trucks. Appropriate research and design may develop systems which can deal with this. For example, a pair of wire rope barriers set 300 mm apart may successfully laterally contain vehicles in this type of location.

However, consideration of this or other alternative ideas will be stifled by the specification of large loads as the only acceptable criterion for barrier design, with consequential large cost increases, especially for barriers on elevated roadways. There has always been a problem reconciling the specification of road and bridge barrier performance criteria. It is a problem for which Austroads must develop a globally integrated rational approach. Unfortunately the adoption of these large bridge barrier loads has exacerbated the problem instead of assisting in its resolution.

## 5 REFERENCES & NOTES


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