East Tamar Highway Rail Bridge Damage, Repair and Replacement

Graeme Roberts, Bridge Asset Manager, *(Department of Infrastructure, Energy and Resources)*
D Coe, Director (Pitt & Sherry),
Aaron Brimfield, General Manager Structures (VEC Civil Engineering)

Synopsis

On 1 July 2008 an excavator being transported on a low loader struck a rail bridge over the East Tamar Highway near Bell Bay in northern Tasmania.

Significant damage was caused to the bridge structure resulting in its immediate closure to rail traffic and closure of the highway for 24 hours whilst the damage was assessed.

Within two weeks repairs sufficient to allow rail traffic to resume were carried out. Within eight weeks of the impact the damaged structure was lifted out and a new structure installed.

This paper will discuss the response and recovery phases of this incident and highlight the partnering approach adopted by the owner, the rail operator, the consultant and the contractor.

Introduction

The Tasmanian railway network consists of approximately 650km of track with 350 bridge and culvert structures. Apart from the occasional tourist train, the network is used exclusively for transporting freight over the following lines:

- The Western Line from Western Junction, to Burnie.
- The South Line from Hobart to Western Junction.
- The Bell Bay Line from Western Junction to Bell Bay.
- The Fingal Line from Conara Junction to Fingal and
- The Melba Line from Burnie to Melba Flats

Over recent years, the responsibility and management of the rail infrastructure has gone through a cycle of public, private and back to public ownership. The current status of managing the rail network in Tasmania is:
The track and land is owned by the Tasmanian Government (except for the Melba Line) and managed through the Rail Management Branch (RMB) of the Department of Infrastructure, Energy and Resources (DIER).

Pacific National Tasmania (PNT) are responsible for undertaking all track Maintenance.

In addition, PNT are the sole train operator and provide train control services.

The Bell Bay line was constructed in the 1970’s and forms a vital link to one of Tasmania’s major ports at Bell Bay, approximately 50km north of Launceston. The track crosses the East Tamar Highway, main highway servicing the port and heavy industrial sites, at a number of locations. Typically the bridges have a reduced vertical clearance of approximately 4.9m, including the subject bridge, B43.01, that was hit.

Bridge B43.01, as illustrated in Figure 1 below, is a single span rail underpass structure spanning over the East Tamar Highway, approximately 22.1m in length. The single track ballast top structure comprise 2 steel beams approximately 1350mm deep and a composite insitu concrete deck. Behind both abutments there is slab spanning transversely between the wingwalls to form a void behind the abutment wall.
The Incident
On the afternoon of Tuesday 1\textsuperscript{st} July 2008 a truck transporting an 20 tonne excavator in a southerly direction impacted the bottom flanges of both the steel beams on Bridge 43.01. The excavator was loaded with the bucket lowered onto the deck rather than crowded in near the cab. As a result the boom knuckle was about 6m above the road. The bridge clearance was about 4.9m. The truck was reported to be traveling at about 100 km/hour.

The impact was very energetic and resulted in the following damage:
- 400mm lateral deflection and buckling of the bottom flanges of both steel bridge beams with significant localised damage to the beam flanges (Refer Figure 2 below).
- Lateral movement of bridge superstructure of 200mm with extensive damage to the southern abutment curtain wall with extensive spalling of concrete (refer Figure 3).
- Displacement of bearings and shearing of bearing bolts.
- Cracking to the reinforced concrete pedestrian refuges on the bridge deck.
- The impact severed the hydraulic ram on the excavator arm and dragged the excavator half off the deck of the truck trailer.

Figure 2 - 400mm Lateral Deflection of Bottom Flanges
Figure 3 - 200mm Lateral Deflection of Bridge Superstructure

Immediately following the incident, the East Tamar Highway, was closed to all road traffic and train operations on the Bell Bay line were suspended. At an early stage PNT, as maintenance manager of the line, called in Pitt and Sherry (P&S), consulting engineers and VEC Civil Engineering (VEC) to provide assessment and assistance. Other key stakeholders throughout the incident management process were:
- DIER – Roads & Traffic Division, Rail Management Branch
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- Police
The following three priorities were identified for dealing with this incident:

1. Undertake emergency repairs to the damaged structure to allow the East Tamar Highway to re-open.
2. Develop and implement temporary support arrangements to allow rolling stock stuck at the Bell Bay terminal to be brought back across the bridge.
3. Develop options for the permanent repair (or replacement) of the structure to allow unrestricted rail access over the bridge and on the highway underneath.

**Priority 1 - Emergency Repairs**

The immediate concerns preventing the road from reopening were the risk of additional damaged concrete falling from the bridge onto the road and possibility of another impact on the structure, which would most likely cause collapse of the bridge given the reduced bearing conditions at the Southern Abutment.

It was agreed the road could be re-opened following implementation of the following measures:
- Removal of all loose concrete from the deck that may fall onto the road underneath.
- Install height warning gantries either side of the bridge to minimise the risk of another truck catastrophically impacting on the structure.
- Installing variable message board signs to advise road users of a reduced height clearance.

Twenty four hours after closing the structure, all loose concrete material had been removed and two height gantries were in place. This allowed the road reopened to traffic with a lane closure and speed restriction in place.

**Priority 2 - Temporary Support Arrangements**

As soon as the emergency repairs were effected, the focus changed to the temporary repair of the damaged structure. Although the road was opened, there was still a locomotive and wagons trapped at Bell Bay. This caused a severe disruption to PNT’s rail services with loss of availability of rolling stock. Importantly, customers could not use the rail network to transport freight to Bell Bay. This caused problems to the state’s transport task with road transport needing to be used to transport freight to Bell Bay or the remaining rail cargo transferred to the Port of Burnie, over 150km away. To cope with the additional road freight task additional trucks were brought into the state from the mainland. It was agreed at an early stage that a temporary repair to the structure needed to be implemented as soon as possible.
Following an initial assessment, it was clear the damage to the structure was severe and that substantial repairs were required before it could be reopened to rail traffic. The extensive damage to bottom flanges of the plate girders would cause high out of plane forces under load and the support of the superstructure at the south abutment was unstable.

**Design**

The design of the temporary repair focused on allowing the existing trains using the network to use the bridge under restricted conditions. The following parameters were used to develop the design for the temporary repair:

- Design load of a 180 LA train configuration
- Live load factor, $\lambda_{LL}=1.4$
- Reduced Dynamic Load Factor of 0.1 with a maximum speed on the structure of 20km/hr

The temporary repair solution involved providing:

- Steel columns under the existing beams at the eastern abutment which were anchored to the top of existing footing. This provided lateral support of the existing structure replacing the damaged bearing.
- A prop under the most heavily damaged section of the beams, approximately 5m from the east abutment founded on a concrete pad footing (Figure 5)
- Transverse bracing to the bottom flanges of the damaged beams (Figure 5)
- External vertical stiffening to the damaged beams at the same location as the transverse bracing (Figure 4)
- In the region of the prop, inclined stiffeners attached to the webs between the bracing bays.

The design philosophy behind the repair was to treat the top and bottom flanges of the plate girder as the top and bottom chords of a truss. The additional bracing and vertical stiffening acted in the way that diagonal members would in a truss. The bottom flange of the plate girder was to be cut at the prop location, effectively producing a two span under-truss bridge.

The solution required one lane of the East Tamar Highway to be closed to traffic until a permanent solution can be implemented.

Forty-eight hours after the road was re-opened, the concept solution was agreed allowing VEC to commence work while P&S continued with detailed design over the weekend. The design was developed in a staged manner to allow fabrication and installation work to commence with a minimum of delay.
**Construction**

VEC were able to mobilise a considerable team at short notice comprising nine boiler makers onsite, two boiler makers offsite, three construction carpenters and a supervisor. The work was carried out under a two lane closure (leaving one lane for traffic) managed by subcontract traffic controllers.

With the rail line closed it was an ideal opportunity to resleeper the bridge. Resleepering the bridge would normally have taken place between trains and had to be done in multiple short sections to ensure the track was always able to take a train. That process would take many days. With these constraints removed resleepering of the bridge was undertaken in 3 days.

![Figure 4 – External Stiffening of Damaged Beam](image1) ![Figure 5 - Transverse Bracing of Bottom Flange and New Prop](image2)

**Risk Assessment and Commissioning the Repair**

Prior to re-opening the bridge a formal risk assessment was undertaken with all key stakeholders to consider the likely issues associated with re-opening the bridge. The risk assessment identified the following key issues:

- There was a need to implement a formal commissioning process for the repair.
- Train operating procedures across the repaired bridge needed to be documented and implemented.
- Ongoing inspections of the bridge were required until a permanent replacement could be installed.
- Traffic management measures needed to be maintained and monitored on the East Tamar Highway
- Regular road safety inspections were required.
As the existing structure had been severely damaged, the design was verified through a combination of calculation and testing. The verification process had the following Hold Points:

- Completion of construction drawings for the temporary repair
- Inspection of the As-Constructed repairs
- Completion of Static Load Tests
- Completion of Dynamic Load Tests

Once the repair work was completed and the inspection completed, the bottom flange was cut at the new support and the static load testing was undertaken. Survey targets were established at critical locations on both sides of the structure. The loading on the bridge was incrementally increased, with the train moving slowly into position and kept stationary while the deflection readings were taken, as shown in Figure 6.

![Figure 6 - Final Stages of Load Testing with Locomotives on Bridge](image)

Broadly the staged loading comprised:

1. Empty wagons.
2. Loaded Wagons.
3. Locomotives, and dynamic tests.
The bridge performed very well with deflections less than predicted for both static and subsequently dynamic loading. The bridge was then reopened to rail traffic to operate within the given constraints on 12th July 2008, just 11 days after the initial incident.

Priority 3 - Permanent Replacement of the Structure

Although the temporary repair allowed trains to use the bridge and road traffic to operate under the bridge, there were significant operating constraints in place for both rail and road users. As a result the quick implementation of a permanent solution became important after reopening of the structure.

Continuing the collaborative approach that had successfully delivered the first two stages of the project, all stakeholders came together to agree the constraints and risks associated with implementing the permanent solution. The constraints on the permanent repair included:

- Minimum closure of the rail line during construction
- Minimal disruption to the highway traffic during construction
- Increase roadway clearance – if practicable
- Meet current design codes including loadings

The associated risk assessment considered the following:

- Project Establishment – stakeholder management.
- Understanding Roles and Responsibilities.
- Treatment of existing structure.
- Project Financing.
- Bridge Design.
- Preparatory Works.
- Closure of Road.
- Public/Media.
- Demolition and disposal of existing bridge.
- Lifting of old bridge.
- Installation of new bridge.

A variation on the standard super T beam bridge was proposed which could achieve all these outcomes.

Design of the New Bridge

It was clear at an early stage the existing superstructure could not be repaired effectively to meet the above operating constraints and it was decided it should be replaced with a new superstructure.
The design developed by P&S in conjunction with VEC was focused developing a design that allowed the damaged superstructure to be removed and the new one installed and commissioned within a two day period. The solution involved modifying a standard T-Roff beam to have the deck and ballast retainers cast in the precasting yard and transported complete to site. Once erected the two beams had to be transversely post-tensioned together prior to installing the ballast and track, as shown in Figure 7 below.

![Figure 7 New Permanent Superstructure](image.png)

The depth of the new superstructure was 300mm less than the original superstructure which allowed the roadway vertical clearance to be increased. As a result precast concrete packers needed to be fitted to the abutments. These packers also provided a means of lateral restraint for the new superstructure.

**Construction**

At nearly 60 tonnes, transporting the beams from VEC’s precasting yard in Ulverstone to site was a major challenge. VEC owned one trailer capable of
carrying the beams but the timing of construction meant two were required. There were no other options in Tasmania and another truck and trailer from Melbourne had to be brought in. Both the VEC and imported trailer were capable of spreading the load to conform with DIER axle load limits, and incorporated rear bogie steering to enable the trailers to readily negotiate corners and be placed for the lifts.

Using a 160 tonne and a 100 tonne crane over a weekend the careful planning of the whole operation went very smoothly as follows:

- The track and ballast was removed. One crane was used to lift out the track sections in 12m lengths. An excavator and concrete kibble removed the ballast.
- The removal of the existing 80 tonne steel beams and concrete deck superstructure of the existing bridge required two cranes in dual lift. This avoided the need to cut the bridge up insitu (refer Figure 8)
- New packer slabs were bolted and grouted to existing abutment shelf provided a new bearing shelf at the raised level.
- The same two cranes lifted the new beams into place. Weighing around 60 tonnes the first lift was a repeat of the removal operation (Figure 9). The second beam required more coordination. One crane had to reach over the installed beam to pick it up. This resulted in the cranes working near their limit. The placement required the end of the second beam to be lifted within 900mm of the crane driver’s cab.
- The beams were secured together using a 26mm diameter stress rod passing through ducts in the beams and hand tensioned.
- A keyway between the beams was filled with rapid set concrete.
- Ballast and the track was replaced and tied into the existing track.
- The following day the stress bars were tensioned to the required load and grouted.

![Figure 8 Removal of existing Superstructure](image1)

![Figure 9 Installation of New Beams](image2)
**Bridge Re-Opening**

The bridge replacement was completed and reopened to rail traffic in 3 days with the East Tamar Highway closed for part of Saturday and part of Sunday. The new bridge was reopened to rail traffic less than eight weeks after the initial incident.

**Summary**

The incident demonstrated how important rail is to the Tasmanian freight task. Without rail access into the major port of Bell Bay, significant transport inefficiencies were introduced.

The management of the rail network, especially during an emergency, requires the cooperation of a variety of stakeholders including government, maintainers, operators and service providers. When all parties work together in a collaborative manner outstanding outcomes can be achieved.

Proactive planning and risk management is essential and can mitigate many issues before they arise.

Stakeholder consideration and management was vital throughout the project. Through the implementation of an effective communication plan, there was were no complaints, and even praise from some!

Importantly, the commercial arrangements were agreed early in the process.

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