Safety and Innovation are part of the delivery of the ALPURT B2 motorway extension in New Zealand

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ABSTRACT

1. This paper will discuss the safety improvements and innovation used to deliver the 7.5km extension to Auckland's Northern motorway in New Zealand. The project has been delivered by the Northern Gateway Alliance, with Owner-Participant Transit New Zealand, and 5 non-owner participants. The paper will illustrate the step change that has taken place, improving the specimen design with many safety issues to the final design that has achieved far more than was expected. Part of this process included challenging standards and developing new ways to mitigate effects on the environment to accommodate a motorway through the rugged terrain.

The issues listed below are some of the items to be discussed:

- Improvements in level of service and speed profile
- Headlight angle used to determine sag curve length
- Reducing road side barrier in cut situations
- Addressing accident migration
- Water flow path depth calculation
- Added value of an alliance delivery method
- Benefits of a deep-lift asphalt pavement

The Alliance had as its vision: "To create a Northern Gateway that is a visual showcase of environmental and engineering excellence", which was used to challenge the team to deliver a project that exceeded the normal road construction projects. I will discuss how we kept seeking better ways of doing things, both in design and in construction. For example in design, a new bridge hand rail was developed that may be adopted as a standard in New Zealand.

1. INTRODUCTION

The ALPURT B2 Project is located 30 km north of Auckland City, New Zealand's largest city with a population of 1.3 million.

At a total cost of $360m, the 7.5km Northern Motorway Extension of State Highway 1 between Orewa and Puhoi was Transit's largest ever capital project. Once completed, the motorway will improve transport infrastructure and support the economic and social well being of Northland, Rodney District and the wider Auckland region. *(Refer attachment 1)*.

The project is being delivered by the Northern Gateway Alliance, (NGA) and includes the full delivery of all facets of the project; design, construction and project management.
The Alliance members are:

- Transit New Zealand TNZ, (the owner)
- Fulton Hogan & Leighton Contractors, (the constructors)
- USR New Zealand, Tonkin & Taylor, Boffa Miskell, (the designers)

The project is scheduled for completion in early 2009.

1.1 ALLIANCING

The alliance delivery method was selected to manage the project as there were significant risks that could be managed better with a full delivery method. This was also the first project to be delivered under the then new legislation, the Land Transport Management Act, (LTMA) which allowed for tolling.

These risks included:

- Uncertainty of funding, scope, design, and consenting
- Geotechnical uncertainty, environmental requirements, and tunnel construction requirements
- Urgency to deliver owing to Environment Court ruling

The word alliancing can apply to a whole range of business arrangements, but on this project it is essentially a form of project delivery. All the participants in the Northern Gateway Alliance work as a single, integrated team to deliver the project. They also operate under a contractual framework where their commercial interests are aligned with actual project outcomes. Alliancing allows no opportunity to sue other participants, (i.e. no disputes), and all parties take collective responsibility for the successful completion of the project on time and within budget.

Financial incentives are provided to encourage outstanding performance and penalties if performance is below standard, (known as pain share/gain share). A 3 limb payment system is part of this project. All parties take collective ownership of the project's risks and opportunities. Alliances are particularly suited to complex projects and where the interests of the community, environment, business and Government must all be considered.

1.2 PROJECT SCOPE

The ALPURT B2 route passes through a historically rich and diverse landscape containing steep topography, large tracts of native bush, regionally significant and environmentally sensitive streams and estuaries and areas of pastoral farmland.

Along its 7.5km route ALPURT B2 passes through four main ridges and five catchments, including the Waiwera Estuary and Nukumea and Otanerua Streams. Three viaducts have been constructed to cross these areas. Twin bore tunnels have been constructed through the northern ridge, Johnstone's Hill to reduce impact on the environment and improve road alignment.

Within these extents of work, one interchange will be provided at Orewa. The Northern Termination has north facing ramps only. Existing local road cross connections at Fowler Access Road, Weranui Road and Hillcrest Road will be maintained.

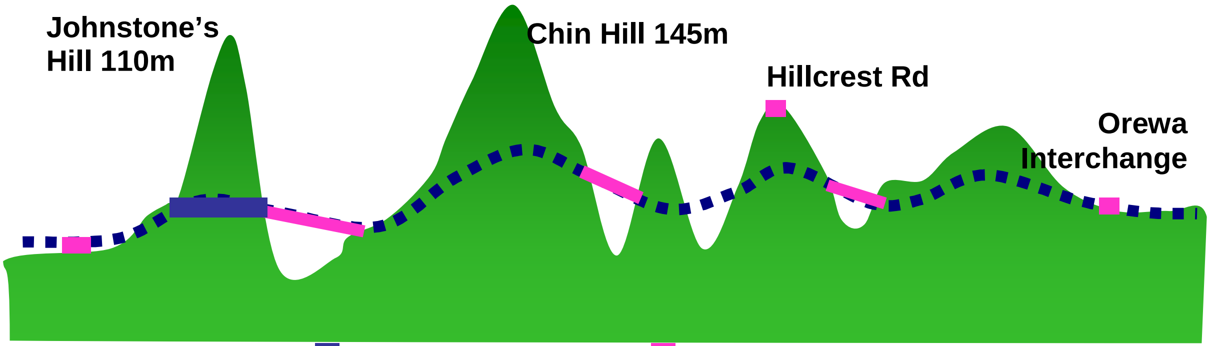


Figure 1 **Tunnel** **Bridges/Viaducts**

1.3 PROJECT COMMENCEMENT

On award of the project the Northern Gateway Alliance was tasked with the delivery of a motorway that was consistent with the project vision:

'To create a Northern Gateway that is a visual showcase of environmental and engineering excellence.'

This required a step change in the design and construction process as the specimen design at the time had many issues that made it unacceptable in light of the project vision. There were also many risks as mentioned earlier that the Alliance either had to eliminate or mitigate.

2. PROJECT IMPROVEMENTS

2.1 GENERAL

This section discussed a number of improvements that the team developed to meet the project vision. As an Alliance, time and money were invested in developing good working relationships, to enable the team (which had come together from six different company cultures) achieve game breaking results. The training included team building days, workshops on communicating and listening, and how to run effective meetings.

2.2 ALIGNMENT IMPROVEMENTS

The geometric design had been developed to an advanced stage following several major changes in scope, including an approval by Transit New Zealand's (TNZ) Scope and Standards Review Committee (SSRC) to delete the south facing ramps at Waiwera Interchange, and a decision by the Transit Board to fund a tunnel through Johnstone's Hill, two Waiwera structures (providing for 4 lanes rather than 2 traffic lanes) and the Nukumea eco-viaduct.

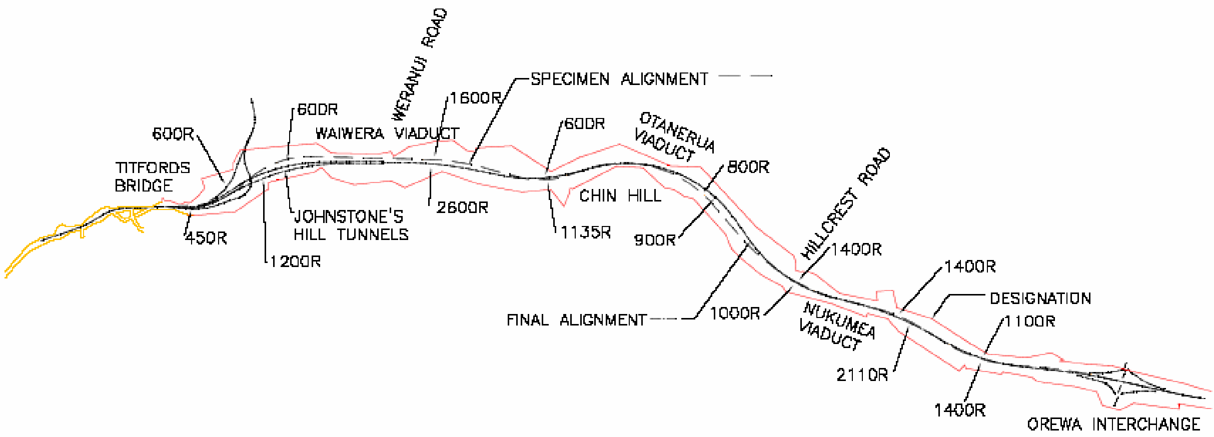


Figure 2 Horizontal Alignment Improvements

A major constraint to improving the vertical and horizontal alignments was the narrowness of the motorway designation. (*Refer figure 2 & 3)*. There were a number of locations where improvements could be made but widening of the designation would be required. NGA has successfully obtained over 70 new resource consents and designation changes, something that would never have been considered under a design and construct contract. This has been achieved by the NGA backing themselves to obtain the desired out come and working closely with the regulatory authorities. The most significant resource consent being a notified consent in the coastal marine area, to allow safety improvements at the northern termination to the project. *(Refer section 4.3)*.

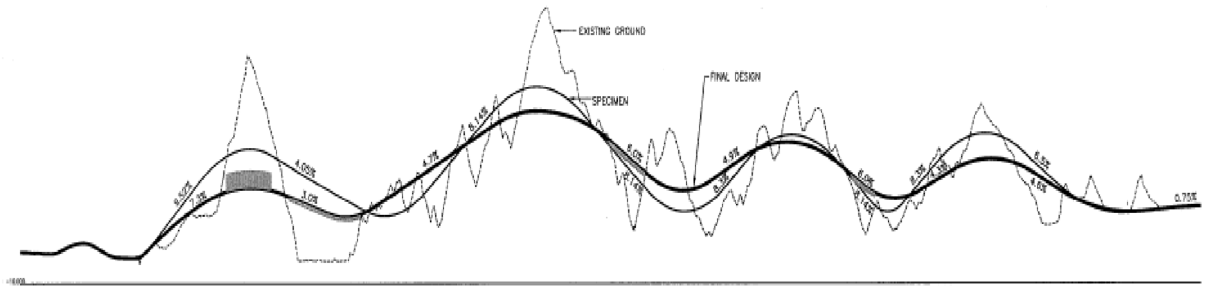


Figure 3 Vertical Alignment, Specimen design & Final Design

These changes along with further design refinement addressed the many Safety Audit Issues that had been identified in a 2.5 safety audit undertaken on the Specimen Design.

The auditors commented on the improved coordination of the horizontal and vertical alignments, stating, "…the mainline alignment south of the tunnels is superior to any others so far put forward for safety auditing at any stage of this project." Coordination of horizontal and vertical alignment has been achieved along with an increase in minimum horizontal radii from 600m to 900m. The vertical curves have also improved allowing for an increase in the design speed from 87 KPH to 100kph. The final crest curve improvements took place more than 12 months after the commencement of construction, with close coordination between the designers and constructors as changes in the mass haul were required, (refer figure 3). These changes involved lowering the Westhoe Ridge cut by 4 metres and the Hillcrest cut by a further 1.5 metres.

The alignment improvements while improving safety also increased the speed profile for heavy commercial vehicles, (HCV) and the level of service. This was achieved by reducing gradients for example from 8.5% to 4.5%. The reduction in gradients has the added safety benefit of reducing the speed differential between fast and slower traffic, and allowing for less fuel emissions which has a significant long term benefit. Table 1 below is a summary of the speed improvements on the uphill gradients shown in attachment 3 for south bound HCV's assuming a maximum speed of 90kph, the legal limit for HCV's in NZ. (*Refer attachment 2 for the speed profiles).*

Location	Specimen Design	Final Design	Improvement
Johnstone's Hill	28kph	55kph	27kph
Chin Hill	26kph	47kph	21kph
Hillcrest Road	48kph	69kph	21kph
Westhoe Ridge	45kph	73kph	28kph

Table 1; Summary of Speed Improvements for HCV's, (south bound)

2.3. CULVERT DESIGNED FOR FISH PASSAGE

Conditions of consent issued for this project required fish passage to be provided for perennial streams crossed by the motorway alignment. A further condition stipulated that passage had to be available for 90% of the time during the whitebait migration period between September and February. Based on habitat survey, culverts had to become fish passes fit for the weakest swimming of the fish species present (being inanga) at six stream crossings.

Although fish passage had been a condition on previous projects a suitable long lasting solution had not been found. Previously wooden blocks had been fixed to the inside of the culverts, these had not lasted.

An innovative approach was taken to the design of the culverts to provide in-culvert habitat opportunities as well as fish passage. This was done by building a series of artificial riffles within the culverts. Water was ponded behind each riffle to form a pool extending to the base of the next artificial riffle. The riffles were created by the placement of pre-moulded plastic sheets 2.4m long at set distances. A matrix of rocks, pebbles and sand was embedded around spoilers moulded onto the plastic sheets. This new system is now being used on other projects through out New Zealand.

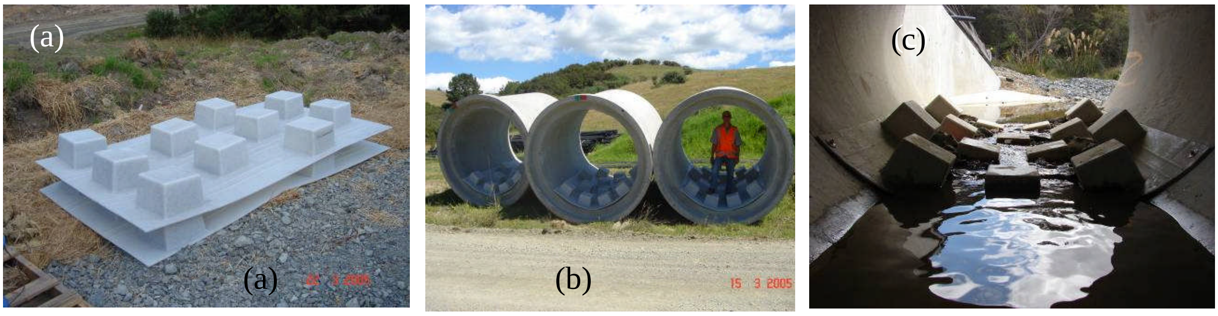


Figure 4: Plastic fish spoiler sheets: a) as manufactured; b) placed in culverts and c) installed in culvert as riffles with matrix of natural materials.

It was found that a range of native fishes including inanga, banded kokopu, redfinned bully and longfinned eels were capable of moving rapidly through these modified culverts. In addition, invertebrates including freshwater crayfish and freshwater shrimps have quickly taken up residence inside the culverts. This artificial habitat construction approach has significant potential for environmental mitigation within the large number of culverts at roading sites and other development projects in New Zealand.

2.4 BRIDGE AESTHETICS

The most visually prominent bridge on the new motorway will be Hillcrest Bridge. This bridge crosses over the motorway at right angles and is approximately 25m above the road surface. The specimen design for the bridge is shown below.

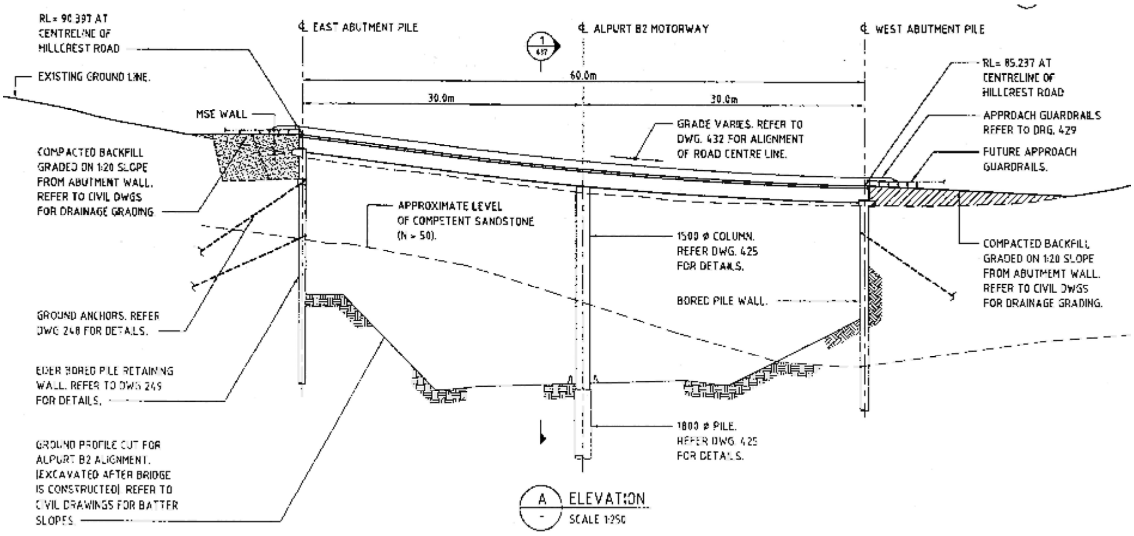


Figure 5. Hillcrest Bridge Specimen Design

The Specimen Design bridge, figure 5 above did not satisfy NGA's vision to "create a visual showcase of environmental and engineering excellence". Multiple design options were considered during detailed design development. The removal of retaining walls on either side of the bridge, created a longer bridge and the low point of Hillcrest Road moved onto the bridge. From an aesthetic point of view, a sag curve on a conventional bridge gives the undesirable impression that the bridge has settled.

In selecting the design option, shown in Figure 6, emphasis was placed on disguising this 'sag' effect with the use of inclined columns with the added advantage that they are structurally logical and the pier on the median, in the original proposal, was able to be eliminated. The final design is enhanced by the curve of the bridge as it represents the former ridge line.

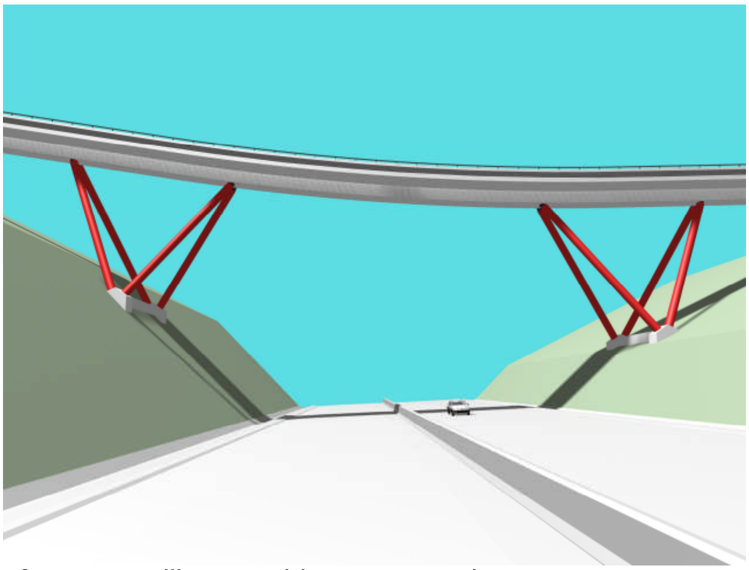


Figure 6. Hillcrest Bridge NGA Design

3. CHALLENGING THE STANDARDS

Road design is New Zealand is required to comply with the standards set out in the State Highway Geometric Design Manual (draft), SHGDM, issued in 2001. The Northern Gateway Alliance was mandated to consider new ways of doing things, to look outside the square and set new standards. This challenge opened the door for the designers to review some of the design standards that previously had been accepted, these included:

- Headlight angle to calculate sag curve length
- Aquaplaning
- Clear zone requirements in cuttings

3.1 HEADLIGHT ANGLE

The terrain through which ALPURT B2 passes is very steep requiring a 'tight' vertical alignment. The specimen design had not allowed for lighting so to comply with the SHGDM either the sag curves had to be lengthened pushing the fills higher or lighting would be required for the entire motorway. There was a strong preference by the NGA not to have lighting for environmental reasons. The design team investigated options to address this issue and identified that the AUSTROADS design guide allowed for an 'effective 1 degree elevation of beam to be used in design due to vertical spread'(Rural Road Design section 8.6). This more accurately represented night driving conditions. This issue was taken to Transit's Scope and Standard Review Committee, (SSRC) for approval. Approval was given and design was completed providing a better over all cost effective design.

3.2 AQUAPLANING

Transit New Zealand recommends that the water film depth (WFD) on a road surface, to reduce the risk of aquaplaning, be kept to a maximum depth of 4 mm. This recommendation comes from the Ministry of Works and Development "*Design Guide for Highways with a Positive Collection System*" published in 1977. A review of recent designs indicated that not all roads in New Zealand been designed to this standard. To maintain the high standard expected on this project, the Alliance was specifically asked by SSRC to propose an appropriate design standard for evaluating WFD. Therefore, once the majority of the geometry had been finalised, the WFD along the route was evaluated.

Figure 7: The Alliance undertook design refinements to reduce the risk of Aquaplaning.

The evaluation involved calculating flowpath lengths and slopes every 20 metres of pavement. The design guide recommends using the 5-minute duration 2-year return period storm rainfall intensity, which was found to be 80mm/hr for the ALPURT B2 site. The approach worked well for straight (planar) areas of pavement and showed that the typical sections, high point and sag areas of the pavement did not pose an aquaplaning risk (assuming no complete blockage of the pavement network drainage).

The most challenging areas were where super elevation was changing and flowpaths curved across the pavement (i.e. warped areas), refer to Figures 8 and 9. The steepness of the ALPURT B2 alignment and its low warp rates in these areas combine to create potentially high WFDs during high intensity rainfalls, which increase the risk of aquaplaning. The highest water film depths were found in these locations. Finished surface contours were examined manually and flow lengths, depths and areas of flow depth over 4 mm plotted.
Water film depths at these locations were initially calculated as greater than the 4 mm depth recommended by TNZ. The Alliance undertook a study of current international best practice in dealing with aquaplaning issues and calculating water film depth. On the basis of the study, the SSRC allowed the Alliance to factor-in and change certain aspects of the road surface. Super elevation warp rates were subsequently increased to shorten the flow path lengths and the porous surfacing (OGPA) adopted by the Alliance was shown to reduce surface water depth.

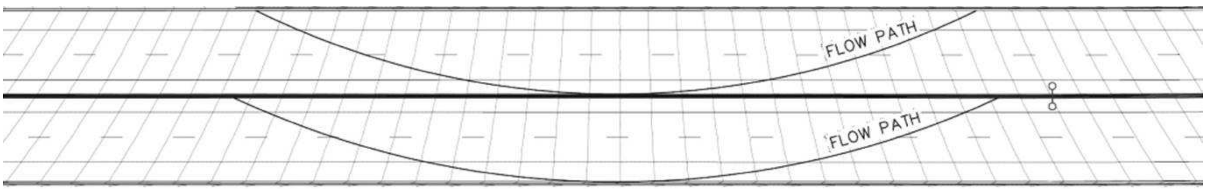


Figure 8: Flowpath for pavement super elevation transition with 1% warp

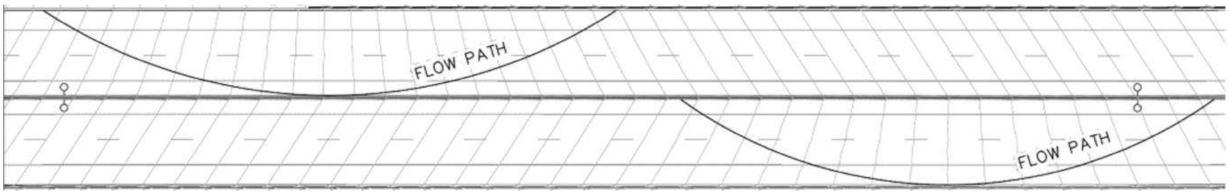


***Figure* 9**: Flowpath for staggered pavement super elevation transition with 2% warp

The study found that in general, the TNZ recommendations were not being widely applied to New Zealand roads due to their conservatism and lack of consideration of behavioural factors. It found that current best practice, particularly in Australia, was to use the Gallaway method for WFD calculations. These findings and the changes made, allowed the Alliance to compute a more realistic surface water depth over the entire alignment. The Galloway formula is now the accepted way of computing Water Film Depths in New Zealand.

3.3 CLEAR ZONE IN CUTTINGS

When considering the project vision, the Alliance is faced with the conflicting constraints of delivering a motorway that meets safety requirements, minimizes environmental impact and provides an optimal 'whole of life' solution while minimising initial cost. The challenge for the Alliance lay in finding ways to optimise each objective.

In order to minimise the environmental impact and to remain within the narrow designation, W-section guard rail was to be constructed along both edges of the road for the majority of its route.

In the Stage 3 safety audit the audit team identified the amount of edge side barrier as a significant issue, and in the close out meeting with Transit's Safety Engineer in Auckland the issue was again raised. The design team was requested to investigate ways of reducing the extent of W section barrier which in itself is a potential hazard and should be eliminated wherever possible. The SHGDM notes that on 'motorways and expressways the desirable minimum clear zone width for 100kph design speed is 9m', (page 6-13). Also the SHGDM section 6.5.2(a) states that "to be regarded as part of the clear zone the roadside area: side slopes must not be steeper than 1:4 on embankments and 1:3 in cuttings"

The design team has identified areas on ALPURT B2 where significant lengths of barrier could be removed in cuttings. However the cut slopes do vary from 1:2 to 1:1 and steeper. The benefit in removing the barrier is that an additional 2.5 to 3.5 metres of clear zone is achieved. While this is less than the required clear zone the increased traversable width can be seen as providing opportunity for vehicle recovery and removing the hazard of the barrier.

We propose that this additional width is 'safer' than if there were a barrier at the edge of the shoulder. We also propose that where a rock face is exposed, the maintenance regime would require the surface to be maintained smooth with no snags.

Figure 10: Unprotected Slope on existing motorway

Historical Accident Data Comparison

We have reviewed the recorded accident data on the section of the SH1 Southern Motorway between the Manukau and Takanini Interchanges. This section of motorway has a number of steep cuts / retaining walls along its length similar to those proposed on ALPURT B2. For the five-year period between 2001 and 2005, there were a total of 268 recorded crashes. Of these crashes 56 involved vehicles hitting a guardrail (either median or roadside) and 10 crashes involved vehicles hitting an upright bank or retaining wall. Of the 10 accidents involving vehicles hitting an upright bank or retaining wall, 3 resulted in minor injuries with the remaining 7 involving no injury to road users.

SUMMARY

The reasons for reducing the amount of W section guardrail include:

- Additional space for a vehicle to recover
- Reduced initial capital cost
- Reduced on going maintenance cost
- Easier maintenance of storm water drainage facilities
- Additional space for motorists to pull off road away from fast moving traffic

A departure was then sought from the SSRC on the basis that even in the absence of a full 9m clear zone, an additional 2.5 to 3.5 metres was safer for road users than a barrier at the lane edge. The SSRC approved NGA's submission allowing the deletion of 2.5 km of W-section barrier for an estimated capital cost saving of $200,000.

The reduction in W-section barrier has significantly improved the road's visual appeal and provides a better integration with the surrounding landscape.

4. FURTHER ENHANCEMENTS

In mid 2006 the Project Alliance Board, (PAB) asked the Management Team, (AMT) to review that what was being delivered, was it in line with the project vision. Could we do better? The AMT prepared a list of items it considered could be improved. These included:

- Tunnel portal treatment improvements, (north & south)
- Long life pavement
- Safety improvements at the northern termination

4.1 TUNNEL PORTAL IMPROVEMENTS

The tunnel portals had been developed initially on a 'least cost' and 'least impact' basis on the existing bush on Johnstone's Hill. The design of the tunnel portals included a shear slope reinforced with permanent rock bolts and mesh. These stark engineering features would have contrasted sharply with the surrounding native forest, and this engaged the team to look at alternative designs. The final recommendation was for an extension to the 'cut and cover' section by approximately 20 metres from the base of the hill and landscaped over the top with soil. In doing this, the natural contours of the hill can be reinstated and the tunnel portal area moulded to a gentler slope. This enables the entire area to be revegetated, so that in the future the tunnel portals will merge with a forested hillside. The final outcome was developed at no additional cost and provided an excellent long term solution. The increase in length being off set by the deletion of the permanent rock bolts. *(Refer figure 11).*

a) Rock face with mesh and Bolts b) Enhanced re vegetated slope
Figure 11 Design Enhancement for southern tunnel Portal

4.2 LONG LIFE PAVEMENT

A review of the pavement specified for ALPURT B2 has been undertaken to ensure that the level of risk inherent in the granular pavement accepted at project award (target out turn cost, (TOC), had been satisfactorily mitigated in its design and specification. Following recent industry experience there have been performance issues with similar pavements on other projects (for example the previous 17km section of the northern motorway known as ALPURT A1, A2, and B1).

The finding of the review was that the current level of performance risk associated with the granular pavement was higher than was apparent and accepted at project award. The level of risk was deemed unacceptable, and it was collectively agreed that as a minimum, the granular pavement design should adopt current industry practice and be amended to:

- Negate the need for the programmed overlay (increased initial construction depth)
- Include a low dosage (1-1.5%) of cement in the subbase and basecourse material to mitigate potential issues with plasticity.

The increased construction depth and the addition of the cement come at a cost premium to the current main alignment pavement budget.
Industry changes since TOC have also effected the design guidelines for asphalt pavement types – effectively providing lower cost asphalt pavements. On the basis of the increase in cost of the modified TOC pavement and the reduced cost of pavement alternatives, a further review was needed to determine if the TOC pavement (with the modifications above) type was still the best for the project on a cost basis.

The cost review included consideration of 'whole of life' costs, and risk based costs, providing the real costs of on going repair and maintenance over 30 years. On the basis of the cost review, a recommendation was made to use a pavement consisting of structural asphalt traffic lanes and granular shoulders.
This decision provided a step change that had been previously thought untenable. The Alliance believed that although there was additional cost in providing a deep lift asphalt pavement the reduction in risk and long term benefits made it the 'best for project' decision. Once again the Alliance chose not to align itself with the status quo of using one pavement across the entire section, instead, constructing the deep lift asphalt in the traffic lanes only. This provided significant savings from the conventional method. *(Refer attachment 3)*

4.3 SAFETY IMPROVEMENTS AT THE NORTHERN TERMINATION

The design for the termination of the ALPURT B2 motorway had been developed to comply with the standards for motorway design as set out in the Draft State Highway Geometric Design Manual. This design has been through a number of safety audits and has completely addressed or lessened the seriousness, of the issues identified.

A Safety Audit carried out in September 2004 indicated that there is a potential for crash migration at the transition from a high speed motorway to a rural highway, and that the designers need to consider what improvements could be made to address this issue.

A report was prepared investigating the benefits of extending the flush median and a median barrier. The report confirmed the statement made in the 2004 Safety Audit Report that the proposed works would be a significant safety improvement.

During consultation with the Department of Conservation it was also identified that there would be significant social benefit if a footpath could be constructed as part of these works. This footpath would form part of a walkway the length of New Zealand, from Cape Rienga to Bluff promoted by the Te Araroa Trust.

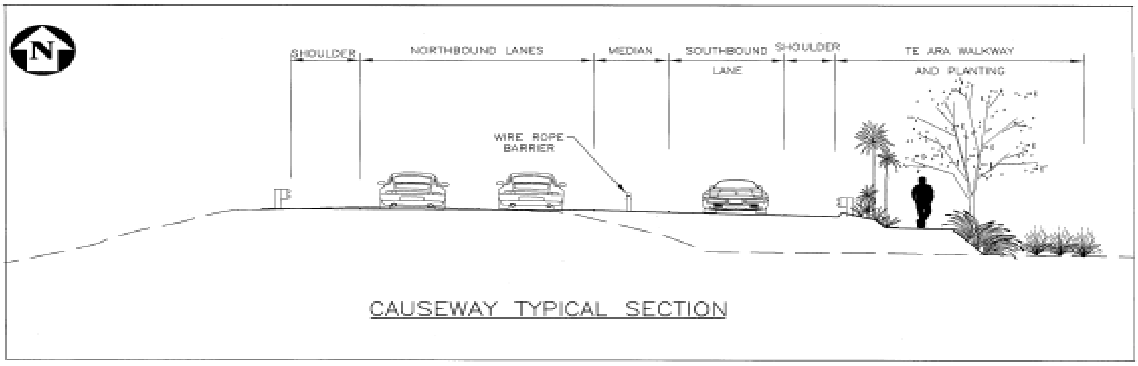


Figure 12: Typical section of widening for safety improvements

The safety benefits of the wire rope barrier are to prevent motorists from overtaking and to cause side friction to encourage motorists to reduce speed, and ultimately to prevent head-on vehicle collisions. *(Refer attachment 4)*.

The wire rope barrier would also prevent vehicles from making right hand turns from SH1 onto a small side road, (Billing Road) and vice versa or performing u-turns on SH1. These unsafe manoeuvres would become increasingly dangerous upon the completion and operation of ALPURT B2, when northbound traffic from the motorway merges with northbound traffic from Waiwera (SH17) in the vicinity of Billing Road. Safe vehicle turning facilities are already provided for northbound traffic at the northern turnaround area and would be provided for local southbound traffic at the Waiwera / Wenderholm off-ramp.

Five accidents have occurred at the first bend north of Titford's Bridge (chainage 852m) since 2002 with three motorists misjudging the corner and leaving the road. SH1 at this location will be upgraded to provide a level run-out area and improve the drivability of this corner.

The previous design required construction of retaining walls on both sides of the highway and in close proximity to the traffic which would be a difficult operation. The proposed works make construction simpler, safer for the workers and less disruptive for the motorists.
The cost of these improvements will be similar to the costs of the previous design as an embankment will be constructed rather than retaining walls. The already widened Titford's bridge will require further widening to cater for the improvements.

To undertake this work a number of resource consents were required necessitating a full notification process and if successful would be signed off by the Minister for Conservation. The team undertook an intense consultation process with key stakeholders and potentially effected parties. Submissions in support were obtained from five stakeholders and one in opposition. Further consultation with the submitter in opposition to the works was undertaken. A satisfactory agreement was arrived at allowing the consent to be obtained un-opposed.

These enhancements would not have progressed under a more traditional form of contracting as there were too many risks both to cost and programme. They have been achieved through the full integration of the team, client, constructor and designer all working together for the best for project outcome.

5. SUMMARY

When the Northern Gateway Alliance commenced work on ALPURT B2 we knew there would be many challenges to overcome and the way to succeed was to work as one team making decisions on a 'Best for Project' basis. The Project Vision "To create a Northern Gateway that is a visual showcase of environmental and engineering excellence" has been central in focusing the team on what was expected.

The results so far have gone well beyond what was envisaged. This paper illustrates some of what the team has achieved and how the culture developed in alliance contracting can have significant benefits for Client, Constructor and Designer.

REFERENCES

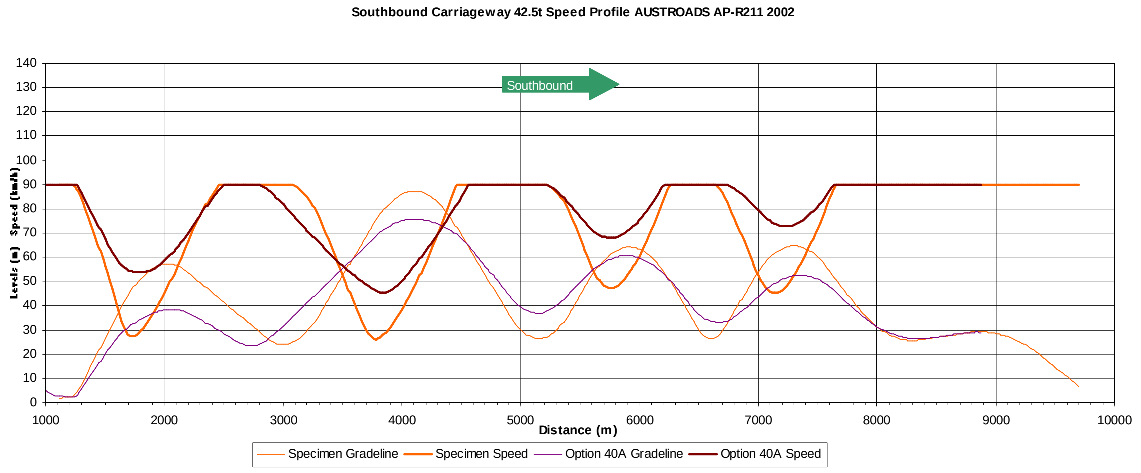
Draft, State Highway Design Manual, Transit New Zealand, (November 2005)

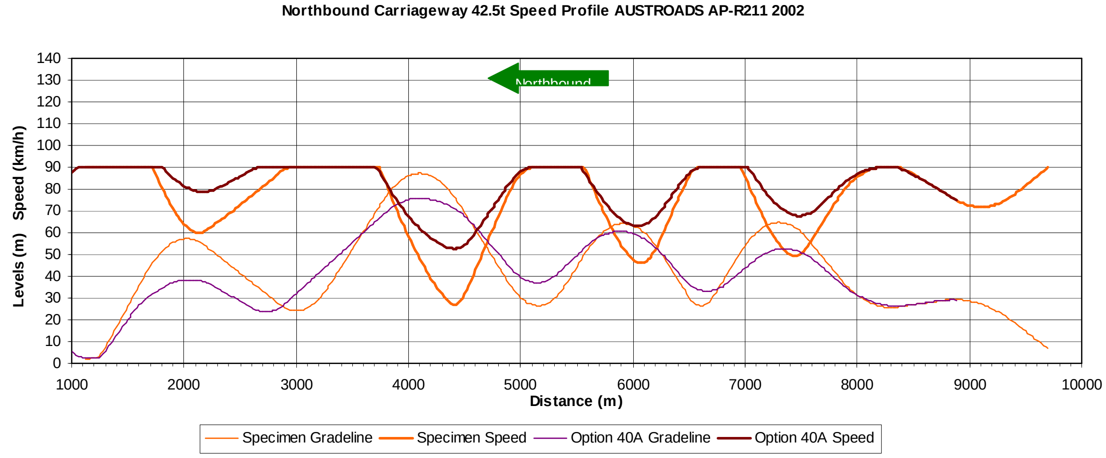
AUSTROADS Rural Road Design, (2003)

J Chesterton, The Use of the Gallaway Formula for Aquaplaning Evaluation in New Zealand, Transit New Zealand and New Zealand Institute of Highway Technology (NZIHT) 8th Annual Conference, 2006.

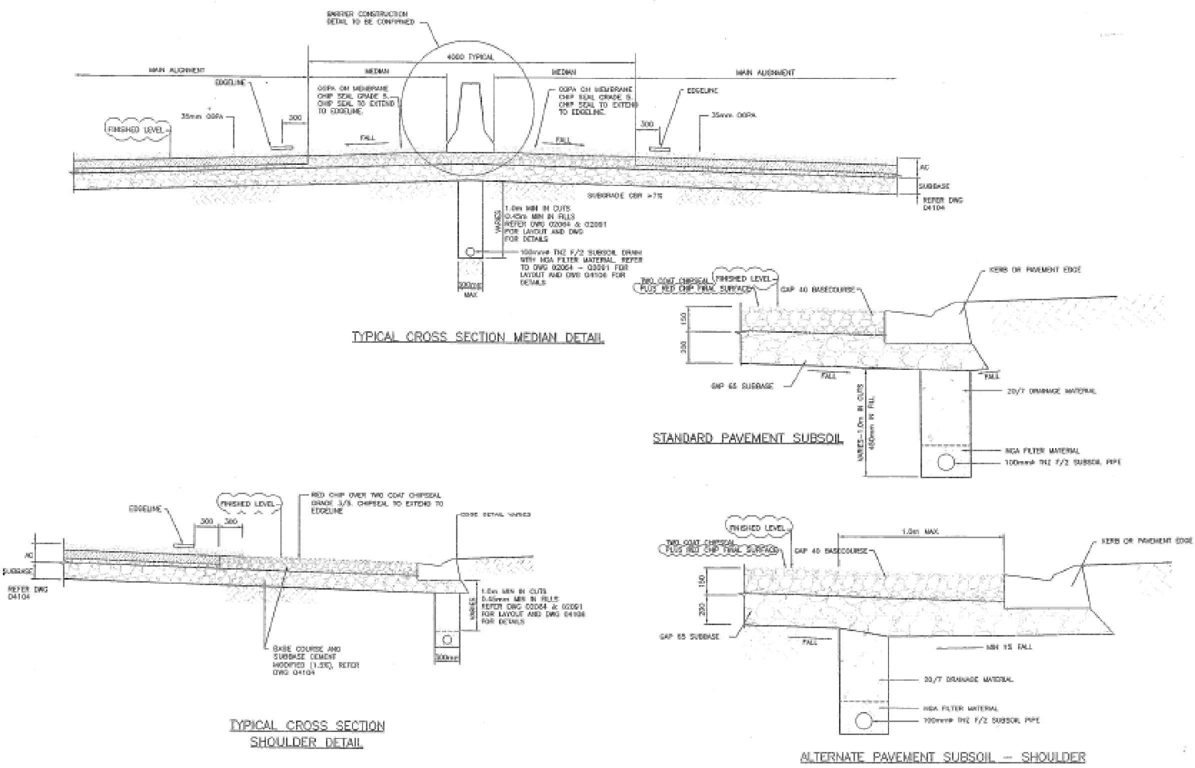
Attachment 1 Location Plan

Attachment 2 Speed Profiles





Attachment 3 Typical Pavement Section



Final Pavement Design

Attachment 4: **Layout Plan of Safety Improvements**