NZTA & NZIHT
13th Annual Conference
2012

Sustainable Pavement Design in Christchurch Southern Motorway

Dr Bryan Pidwerbesky – General Manager Technical
Fulton Hogan Ltd, PO Box 39185, Christchurch 8545, New Zealand
Tel: +64 3 357 0615
email: bryan.pidwerbesky@fultonhogan.com

Geoff Griffiths – Project Manager NZTA
NZTA, PO Box 1479, Russley, Christchurch 8140
Tel: +64 3 963 5510
Email: geoff.griffths@nzta.govt.nz

Ben Hayward – Construction Manager Christchurch Southern Motorway
Fulton Hogan Ltd, PO Box 39185, Christchurch 8545, New Zealand
Tel: +64 3 322 5733
email: ben.hayward@fultonhogan.com

1. Introduction

The Christchurch Southern Motorway Stage 1 (CSM1) was the first of the large projects to commence construction that together make up the Christchurch Motorways Roads of National Significance (RoNS). CSM1 is the first of three stages that make up the southern highway corridor to Christchurch. The northern corridor and the western ring route form the other legs of the Christchurch RoNS package.

The CSM1 project consists of three quite distinct Zones. Zone A involved the rehabilitation and widening of 2.5kms of the existing Halswell Junction Road, including the conversion of Shands Road roundabout into a large signalised intersection. Zone B is a 5km Greenfields 4 lane motorway section with 2 local road underpasses, a river bridge and 2 subways connecting to Zone A at the Springs Road roundabout. Zone C is a 3km duplication of the existing 2 lane motorway to form a new 4 lane system with 2 motorway over-bridges, a subway extension and major interchanges at both Curletts Road and Barrington Street.

Traffic volumes and even forecast long term use of these sections of road are also quite different. The duplication section, Zone C, is expected to carry approximately 41,000 vpd on opening in early 2013. The greenfields section, Zone B, will carry approximately 21,000 vpd on opening. Halswell Junction Rd, Zone A, will carry approximately 21,000 vpd south of the Shands Rd intersection and 13,000 vpd north of the Shands Rd intersection. In addition on completion of Stage 2 of the Christchurch Southern Motorway Halswell Junction Rd will revert to local road as the motorway traffic uses a future new 4 lane motorway that will be built connecting Zone B of CSM1, at Springs Rd roundabout, essentially to Rolleston.

2. The NZTA's Sustainable Approach – What NZTA set out to Achieve

The CSM project is a Design / Build contract. This always means that care needs to be taken to ensure that both the Scope of Work and the Principal's Requirements clearly reflect and define the outcomes expected.

In the case of the CSM1 project two of the key criteria that the NZTA were keen to deliver were extending the work already underway within NZTA on sustainability in construction and maintenance activities and to further develop the balance between capital costs and long term maintenance costs, (sustainability in whole of life).

In respect to sustainability in construction one of the more unusual aspects of this project was the award two years prior to the CSM1 construction contract of a supply contract for 60,000 cu.m of recycled crushed concrete. This was then written into the CSM1 contract as a Principal Supplied item with a condition that it must be used within the pavement. NZTA had already carried out a lot of work proving the value of this material within pavements including that it could produce a pavement of superior quality to those utilising virgin materials. NZTA also encouraged through the CSM1 request for tender and the tender period interactive meetings a sustainable approach by tenderers in respect to both materials and methodology. This paper describes some of those brought to this project by the successful tenderer Fulton Hogan.

The balance between potential additional capital costs and savings in long term maintenance is always a difficult one. It is recognised however that there is a lot that can be done during construction to minimise future maintenance costs at little or no extra cost during construction. The challenge is to capture these early to ensure they can be accommodated within the wider design and that they are well developed when incorporated in the works. One of the more obvious examples of this approach is in the tailoring of pavement design to predicted use whilst future proofing and making the investment in higher quality where the increased expenditure can be justified using a risk analysis. In the case of the CSM1 this is evident in the NZTA specifying the use of a structural asphalt pavement in Zone C, a modified base for Zone B and a rehabilitated pavement in Zone A. Essentially the CSM pavement design philosophy was to focus on maximising value for money, provide a quality low maintenance pavement structure and ensure sustainable use of resources.

This paper goes on to explain the detailed design of these pavements, the minimisation of the use of virgin materials, the reduction in extraction and cartage related energy usage and how over 120,000 tonnes of recycled crushed concrete and 5500 tonnes of reclaimed asphalt pavement (RAP) have been incorporated into the pavements. In addition to this, 66,000 tonnes of low quality RAP was used in the embankment core fill. The paper also describes how leading edge micro-cracking techniques were employed to provide an innovative pavement design

3. Pavement Design Zone A – Widening and Upgrade

The widening and upgrade of Halswell Junction Road (HJR) which formed Zone A involved the construction of a modified pavement. The traffic loading in this Zone was 2.1×10^7 DESA. A cement modified pavement was selected as the most appropriate construction method due to the significant high stresses on this industrial road including turning and side entry movements. Further to this, due to the need to construct the pavements under live traffic, a modified pavement would be able to be heavily trafficked immediately following construction.

3.1 HJR Pavement Design and Methodology

The pavement design involved utilising the majority of the existing pavement structure as the deflections were generally less than 1.2mm and the pavement was made up of clean aggregate with excellent source properties. On investigation, the existing basecourse although a high quality stone, had a significant proportion of rounded stone with the broken faces proportion less than 30% and it was decided that this layer should be modified to increase the percentage of broken faces and create an optimum blend for stabilising.

The final design involved milling out 100mm of pavement which comprised approximately 45mm of wearing courses and 55mm of existing basecourse aggregate. 100mm of virgin aggregate was then replaced and the basecourse layer was stabilised to a depth of 150mm, resulting in a layer with a combination of existing and virgin aggregate with the proportion of broken face exceeding 50% and a fines content suitable for stabilising. 1.8% cement was used as the modifying agent.

LAYER	DESCRIPTION	MATERIAL	DEPTH
1	SURFACING	SMA	40MM
2	SEAL	2 COAT 1ST SEAL	
3	BASE	100MM AP40 M4 + 50MM EXISTING BASE + 1.5% CEMENT	150MM
4	SUBBASE	EXISTING HJR PAVEMENT	
5	DESIGN SUBGRADE	CBR 10%	

Figure 1 Typical Zone A Pavement Design

3.2 Sustainable Practices

By utilising the existing pavement and designing a cement modified pavement, this significantly reduced the amount of excavation of old pavement and replacement with new aggregate required. This in turn reduced cartage movements from quarries.

All aggregate that was milled out of the existing road was stockpiled and utilised in the cycleway formation on the project so that no material was wasted.

4. Pavement Design Zone B – Greenfields Motorway

The construction of the Greenfields Zone B motorway pavement involved a combination of unbound and modified aggregate layers. The traffic loading in this Zone was 2.1×10^7 DESA and the turning and braking stresses were minimal. A foamed bitumen modified pavement was designed for this Greenfields section in order to construct a high quality, durable motorway pavement which would have a design life and performance greater than an unbound pavement.

4.1 Zone B Pavement Design and Methodology

The Zone B pavement was founded on either natural in-situ river gravel subgrade, or a subgrade improvement layer formed from imported pit run material. The 250mm thick subgrade improvement layer was utilised in areas where the natural subgrade material in cuts was a moisture sensitive silt layer. The subgrade had a minimum design CBR of 10%; however in all cases the measured CBR exceeded 20%.

The 200mm thick subbase was formed from AP65 Recycled Crushed Concrete (RCC). This material was sourced by NZTA prior to the contract being awarded. The decision to use

RCC by NZTA was based on a both performance (as the RCC is a high quality subbase material) and sustainability reasons.

The 150mm thick basecourse was formed from a specifically designed aggregate blend which was optimised for foamed bitumen stabilising. The layer was then modified with 2.7% bitumen and 1.5% cement using a Wirtgen WR2500 recycler in order to form the foamed bitumen stabilised layer.

LAYER	DESCRIPTION	MATERIAL	DEPTH
1	SURFACING	OGPA	30MM
2	SEAL	2 COAT 1ST SEAL, 1 COAT 2ND SEAL	-
3	BASE	FOAMED BITUMEN AP40	150MM
4	SUBBASE	RCC	200MM
5	DESIGN SUBGRADE	CBR 10%	

Figure 2 Typical Zone B Pavement Design

4.2 Sustainable Practices

By using the RCC which was stockpiled on the project site, this eliminated the need for the extraction and cartage of 120,000 tonnes of subbase aggregate to the project. This would equate to over 4200 truck and trailer movements or 105,000 kms of cartage. Further to this, the use of RCC meant that a product that would typically be disposed of in a clean fill could be recycled.

The use of foamed bitumen technology to form a high quality but cost effective basecourse layer for the client eliminated the need for additional aggregate excavation and cartage that would be required for a thicker unbound pavement. In order to form an unbound pavement with an equivalent design life, a minimum thickness of 75mm of additional gravel would be required on the pavement. In Zone B, this would equate to over 41,000 tonnes of additional aggregate, 1450 truck and trailer movements or 36,250 cartage kms.

5. Pavement Design Zone C – Duplicated Motorway

The construction of the Duplication Zone C motorway pavement involved a combination of heavily stabilised layers and structural asphalt. The traffic loading in this Zone increased significantly compared to Zone A and Zone B with a DESA of $4x10^7$. A cement stabilised RCC subbase and 165mm of asphalt was used to form a heavy duty pavement that could withstand the high traffic counts and increased road stresses in this Zone.

5.1 Zone C Pavement Design and Methodology

The Zone C pavement was founded on embankments constructed from imported gravel. These embankments were typically in the order of 4-5m in height and therefore the subgrade had a conservative design assumption of 10%; however in all cases the tested CBR exceeded 20%.

The subbase was formed from a 200mm thick layer of RCC which was cement stabilised with 3.5% cement in order to form a rigid anvil on which the structural asphalt basecourse could be constructed. The layer was stabilised in-situ using the Wirtgen WR2500 recycler. The subbase layer was specifically designed to be a stiff layer to prevent deflection which may cause fatigue related deterioration in the overlying asphalted layers. However, in order to prevent significant cracking in the stiff RCC subbase layer and potential subsequent reflective cracking in the asphalt layers, the stabilised RCC subbase was micro-cracked using a vibratory steel drum roller on low frequency vibration and high amplitude. This technique induces numerous “micro” cracks in the subbase layer, which prevents the formation of larger shrinkage or flexure induced cracks. In order to ensure that the micro-cracking was occurring (as it is difficult to visually inspect the cracks due to the small size) Benkelman beam testing was undertaken both prior to and post micro-cracking. Following micro-cracking an increase in deflection in the order of 0.2mm was identified in the subbase layer. This increase was significant given that the beam results prior to post cracking were in the order of 0.2-0.3mm. Finally following micro-cracking, a polymer modified membrane seal was applied to the subbase layer to further mitigate any reflective cracking by providing a highly elastic membrane interface.

The 125mm thick structural asphalt basecourse was formed from two layers of 14mm nominal size asphalt mix, designed using KiwiNAS. The structural asphalt mix was specifically designed to incorporate 30% reclaimed asphalt pavement (RAP) whilst still ensuring a high quality asphalt layer that met all the performance-based testing requirements. A 40mm stone mastic asphalt or open graded porous asphalt wearing course was applied over the 125mm structural asphalt base providing the total asphalt depth of 165mm.

LAYER	DESCRIPTION	MATERIAL	DEPTH
1	SURFACING	OGPA	40MM
2	TACK COAT	POLYMER MODIFIED	-
3	STRUCTURAL ASPHALT BASE	MIX 20	125MM
4	MEMBRANE SEAL	SINGLE COAT 1ST SEAL	-
5	HEAVILY CEMENTED SUBBASE	RCC + 3.5% CEMENT	200MM
6	DESIGN SUBGRADE	CBR 10%	

Figure 3 Typical Zone C Pavement Design

5.2 Sustainable Practices

Similar to Zone B, the use of the RCC supplied by NZTA significant reduced the amount of virgin aggregate extraction and cartage required whilst utilising what would often be a waste product. In addition to this, the use of heavy cement stabilisation also substantially reduced the amount of aggregate that would be required to form an equivalent layer from an unbound material.

The use of RAP in the structural asphalt layers equates to 5500 tonnes of virgin asphalt that is not required to be produced. This equates to a saving of 275,000 litres of bitumen which is recycled.

6. Collaborative Relationship during Design and Construct to form Robust Sustainable Solutions

During the contract period a strong collaborative relationship between the parties involved in this Design and Construct contract has ensured a best for project approach has been adopted. This has extended to refinements in the pavement design and in the pavement construction methodology. The NZTA representative has an office on site and this has allowed issues to be discussed and appropriate actions agreed essentially as and when they arise. NZTA also have their national pavement specialist Dave Alabaster based in Christchurch allowing him to be brought into the project team as required to assist with key decisions. Examples of issues that arose during the project where this collaborative approach assisted were the best use of the Recycled Crushed Concrete, (RCC), product and the refinement of the basecourse grading for the foamed bitumen stabilisation. In the case of the RCC the issue was the variability in the grading of the product. Rather than debate this contractually a methodology was agreed that essentially matched the different material grading to location and proposed treatment. This avoided the need for further additional treatment of the material and a potential contract claim without compromise to the pavement quality. With the basecourse grading a series of stabilisation trials were carried out with basecourse from various sources, each source providing a product with some positive and some negative properties. After analysis of the trial results, consideration of construction methodology, supply risk and cost the project team made a decision on grading that involved a blend to achieve an optimisation of outcome.

The value to a project in having mature and experienced key decision makers available on site cannot be underestimated. While there were at times some relatively robust discussions held, in the end all parties could be comfortable that the decisions reached were on balance best for project, delivered in a timely fashion and with risk and cost apportionment very clear.