MEYER CRUDEN ENGINEERING LTD

ECONOMIC ASSESSMENT HILAB

Prepared for NZTA

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1. INTRODUCTION

Meyer Cruden Engineering Ltd. have been engaged by NZTA to undertake an economic assessment of the HiLab pavement system relative to other established pavement options. This economic assessment considers only capital cost as requested by NZTA.

The HiLab pavement treatment is being constructed on three sections of the Waikato Expressway project: Huntly bypass, Hamilton bypass and Longswamp.

Adoption of the HiLab pavement system has been, in part, a response to premature failures of other more established pavement systems on major projects completed in the last six years throughout NZ.

HiLab is seen by NZTA as a cost effective alternative to Structural Asphalt (SAC).

1.1 Approach to project

In preparing this report the author has undertaken the following background activities:

- Conducted interviews and communicated via email with staff from NZTA, Fulton Hogan, Higgins, Bloxam Burnett & Oliver and Stevenson Group;
- Reviewed tender and negotiated rates for pavement configurations for the Waikato Expressway project, provided by NZTA; and
- Visited the Huntly and Hamilton bypass projects and witnessed aggregate production and construction activities.

2. HILAB BACKGROUND

HiLab has been in development for some 10 years, initially constructed as pavement maintenance rehabilitations in the Waikato region and then subsequently as trial sections within major green field projects on the Waikato Expressway. In addition, the HiLab pavement has been tested at NZTA's Canterbury Accelerated Pavement Testing Indoor Facility (CAPTIF) in Christchurch. Its development has been led by NTZA's Principal Technical Advisor (Pavement) Gerhard van Blerk.

Based on the success of the field trials and CAPTIF testing, NZTA has elected to proceed with HiLab pavements on the Waikato expressway project.

The pavement system comprises a cemented (3%) crushed, coarsely graded large stone/low fines aggregate. The pavement is laid as both a subbase and basecourse layer. A top size of 65mm is used for the subbase layer and 40mm for the basecourse layer.

The system is modelled on the Macadam pavement system developed by Scottish Engineer John McAdam in the early 1800's. The McAdam system comprised clean broken stone, held together by the high aggregate interlock gained from the angularity of the individual aggregate within the pavement.

Visually the HiLab aggregate resembles a railway ballast. Like McAdam, HiLab primarily gains its strength from the high friction aggregate interlock between the stones. The cement component, in conjunction with adequate moisture and the limited fines present, provides a slurry to facilitate compaction and aggregate reorientation during construction. Post construction it is theorised that the cement and limited fines present forms a mortar paste filling remaining voids between the interlocked larger stone.

Traditionally, heavily cemented, more finely graded granular pavements are prone to shrinkage cracking similar in nature to unreinforced concrete. These cracks form in the more continuous fine matrix present. The HiLab system seeks to mitigate against this cracking by carefully limiting the fines content. It is theorised that the fine cement mortar paste in the HiLab pavement does not provide a continuous fine matrix for cracking to propagate through. Thus, grading control is critical to developing the desired properties within the HiLab layer.

Due to the coarse grading of the HiLab aggregate the pavement surface can be less smooth compared with a more traditionally graded aggregate. To aid in creating a pavement surface suitable for surfacing a finer graded aggregate, with a maximum particle size of 7mm, is added to choke up the voids between the larger stones. This creates a smoother surface and helps lock up the near surface larger aggregate to create a stone mosiac surface suitable sealing.

3 ALTERNATIVE PAVEMENT OPTIONS

HiLab pavements are currently deemed suitable and cost effective for high volume roads, which for the purposes of this report, are defined as roads carrying 1x10^7 to 5x10^7 25 year design traffic volume (ESA). Table 7 of the New Zealand guide to pavement structural design, version 1.1, 2018 (NZ Guide) provides some guidance on the suitability of various pavement treatments for sites of this nature, in terms of risk of failure. Low risk options for this range of ESA's include: -

- Continuously reinforced concrete pavement – unlikely to be economic;
- Structural Asphalt – low risk;
- Modified aggregate overlay basecourse and bound subbase – low risk; and
- Foamed bitumen basecourse – low risk.

For the purposes of this economic assessment Structural Asphalt (SAC) and Foam Bitumen stabilised (FBS) pavements have been considered as viable alternatives.

A reinforced concrete pavement has not been considered as it would be too costly.

A modified aggregate basecourse and bound subbase pavement has also not been considered. The risk profile of this solution is currently under consideration based on recent failures of this pavement type.

The specific pavement configurations selected for the comparison have been designed following the guidance provided in the NZ Guide. The Austpads pavement design software has been used to complete the design analysis. Key inputs parameters into the design are as follows:

- The design traffic for the options is 3x10^7 ESAs. This is equivalent to the Huntly bypass main carriageway design traffic.
- The traffic load distribution (TLD) for SAC design purposes has been determined from the Drury weigh in motion station.
- The subgrade CBR adopted for the design is equivalent to that defined for the Huntly project, subgrade CBR 2.
- A 900mm subgrade improvement layer (SIL), has also been included in all designs comprising 600mm of slightly weathered "brown rock" topped with 300mm of unweathered "blue rock". A maximum subgrade CBR at the top of the SIL of 10 has been adopted. This matches the Huntly design requirements. This is considered conservative and it is the view of the author that a CBR of 15 could be considered for design purposes at the top of the SIL. This is discussed in more detail later in the report. The SIL has been modelled as a sub layered selected subgrade layer.

The detailed pavement configurations are as follows:

3.1 Option 1 HiLab – As specified on the Huntly Bypass

Layer	Vertical Modulus (MPa)	Comment
40mm Stone Mastic Asphalt (SMA)	1250	SMA selected due to concerns over OGPA waterproofing
Combined seal coats totalling 3L/m² residual	n/a	3L/m² selected to enhance waterproofing of HiLab
HiLab 40, 200mm	3500/500 post cracked	
HiLab 65, 230mm	3500/500 post cracked	
900mm SIL	100	sub layered
Subgrade CBR 2	20	

Table 1 : Option 1 - As specified on the Huntly Bypass

3.2 Option 2 Structural AC over bound base

Layer	Vertical Modulus (MPa)	
30mm Open Grade Pours Asphalt (OGPA)	500*	SMA not required for waterproofing as SAC itself more moisture resilient than HiLab.
Tack Coat	n/a	
60mm Mix 14 SAC	3300	60mm mix 14 improves ride and moisture resistance
115mm Mix 20 SAC	4400	Min total AC depth must be 175mm over bound subbase to mitigate against reflective cracking
250mm bound subbase,4% cement	3500/500 post cracked	
900mm SIL	100	sub layered
Subgrade CBR2	20	

*Table 2: Option 2 - Structural AC over bound base (*OGPA modulus as per S3.6 NZ Guide to Pavement Structural Design)*

3.3 Option 3 Structural AC over granular base

Layer	Vertical Modulus (MPa)	Comment
30mm Open Graded Porous Asphalt (OGPA)	500	SMA not required for waterproofing as SAC itself more moisture resilient than HiLab
Tack Coat	n/a	
60mm Mix 14 SAC	3300	60mm mix 14 improves ride and moisture resistance
140mm Mix20 SAC	4400	Note – This layer thickness could be reduced to 120mm if the SIL modulus were 150Mpa
250mm granular base	150 (210 if modelled in conjunction with an SIL modulus of 150MPa)	Note this layer depth could be reduced to 200mm in conjunction with the reduced AC

		depth if a modulus of 150MPa were assumed at the top if the SIL
900mm SIL	100	
Subgrade CBR2	20	

Table 3 : Option 3 - Structural AC over granular base

3.4 Option 4 Foam Bitumen base over modified subbase

Layer	Vertical Modulus MPa	comment
40mm SMA	1250	
Membrane seal	n/a	
200mm Foam Bitumen layer (2.7% bitumen, 1% cement)	800	
200 modified subbase max 2% additive	300	sub layered
900mm SIL	100	
Subgrade CBR2	20	

Table 4 : Option 4 - Foam Bitumen Base over Modified Subbase

All configurations achieve the required design life. Whist some further refinement of design could be completed to optimise layer thicknesses the designs provided are considered sufficiently detailed for cost comparison purposes.

3.5 Influence of pavement configuration on surfacing

The HiLab and Foam bitumen options utilise an SMA/membrane chipseal surfacing system for enhanced waterproofing, improved ride quality and enhanced structural capacity (ref G Van Blerk). Recent failures of OGPA/chipseal surfacings over modified pavements (cement only and foam bitumen) has led to a more conservative approach to surfacings over these pavement types. We understand that the HiLab pavements being constructed will receive a full 3L/m^2 combined residual seal coat for waterproofing prior to AC surfacing. It is the view of the author that this level of conservatism is not warranted for the foam bitumen given the inherent moisture resilience of the foam bitumen itself. A residual bitumen application rate of 1.5L/m^2 applied in a single application would be appropriate.

The SAC options do not warrant SMA for waterproofing purposes and instead include a 30mm OGPA/tack coat surfacing. The 60mm Mix 14 upper layer of the structural AC will also provide further moisture resistance.

3.6 Influence of subgrade improvement layer on pavement configurations

During interviews several parties shared the view that the 900mm subgrade improvement layer being constructed on the Huntly bypass was resulting in a subgrade strength at the top of the SIL well in excess of the prescribed design CBR of 10. Whilst NZTA have not amended the HiLab pavement design to reflect a higher subgrade CBR several stakeholders expressed the view that alternative pavement configurations such as structural AC could be designed based on an assumed subgrade CBR closer to the actual subgrade strength being achieved at the top of the SIL.

It is the view of the author that the design subgrade CBR 10/vertical modulus 100 MPa at the top of the granular subgrade improvement layer is conservative and more realistic values could optimise the pavement configurations above. Adopting a subgrade modulus of 150 MPa at the top of the subgrade improvement layer could reduce the required AC depth under Option 3 from 200mm to 180mm and the unbound base layer depth from 250mm to 200mm depth. This design model adopts a modulus at the top of the unbound granular layer of 210MPa. The saving is discussed under section 5 of this report. Whilst some stakeholders expressed a view that the SIL depth could be reduced it is the view of the author that the 900mm SIL reflects good practice but equally its performance properties should be recognised adequately when designing pavement layers above.

4. ESTIMATE APPROACH

The cost estimates for the various pavement configurations have been prepared from referencing recent actual tender and agreed contract rates, obtaining specimen rates from industry, and in addition in the case of HiLab, undertaking cost estimates from first principles. Structural AC and Foam bitumen rates are well developed and understood in the industry.

The rates are inclusive of margin for on and off site overheads and profit.

4.1 HiLab cost estimate background information

During interviews conducted in preparing this report it was conveyed by all parties that industry's' understanding of the real cost of producing a complying HiLab pavement is still developing.

The HiLab pavement production and construction methodology is percieved as more demanding than other current alternatives. During discussions Contractors expressed the view that tighter quality assurance tolerances for HiLab aggregate production and pavement construction have led to the risk of noncompliance being perceived to be higher than for other pavement technologies. This perception could also be in part due to tighter general QA requirements on the current projects
(Quality Right).This perception may or may not prove to be correct but in the interim it is the view of the author that the risk, and importantly the risk of rework associated with HiLab, is perceived by industry to be higher than the alternatives. This impacts on rates. This view is based on discussion with several providers.

In determining appropriate HiLab rates for the comparison we have reviewed previously tendered and negotiated rates and completed a detailed "bottom up" cost estimate. This bottom up estimate includes observations of resources on site during HiLab construction along with consideration of resourcing plans provided by a supplier.

We have also considered feedback from industry on the under estimation of the production costs of the aggregate to date. Aggregate production costs have steadily increased for HiLab. Conversely, balancing the under estimation of production costs, is the value of the by product from HiLab production. The by product has been found to have significant market value as is, or as a raw feed for other high value aggregates.

4.2 HiLab aggregate production process

The aggregate production process for HiLab is different from that undertaken for normal M4 AP40 and AP65 aggregate. The process for a traditional pavement aggregate typically involves a single stream of aggregate being fed through a three to four stage process including pre-screening (if required), a jaw crusher, a cone crusher and a Barmac crusher. Some minor reblending may take place following this production process to adjust fines content.

A HiLab aggregate utilises similar plant but importantly it is processed in separate streams and then blended after production in a carefully controlled manner using additional plant. The blending operation is significant and to date has utilised plant such as a pugmill or batching plant to produce the correct grading.

This production process results in a higher cost to produce HiLab versus a traditional M4 AP40 or 65. Discussion with suppliers and sample estimate rates provided by an aggregate production company indicate that HiLab [redacted] will be in the region of 15-20% more expensive to produce than an NZTA M4 AP40 [redacted].

During interviews, suppliers have indicated that they anticipate a higher rejected batch rate on the HiLab than a normal aggregate due to the tighter grading requirements. Some suppliers have indicated that they account for the higher noncompliance frequency in their rates. It was also raised by some suppliers that they anticipate further cost increases in HiLab production as the aggregate suppliers come to terms with the actual costs.

4.3 HiLab construction process

The construction methodology for the HiLab pavement is highly prescriptive and involves more resource than a normal stabilising operation. In preparing this report the author attended site during the construction of a 4000m^2 HiLab 40 layer. Observations were made by the author of the crew and plant present on site. These observations were used to develop a bottom up cost analysis for the HiLab construction. Resource plans provided by Contractors were also considered. The general process, as witnessed, for constructing HiLab is as follows:

- Initial laying out of the aggregate using grader, water cart if required, 14T vibrating steel drum roller;
- Cement stabilising using 2xcement spreaders and hoe with water cart support to control moisture;
- Primary compaction by way of a 14T smooth drum and 16T padfoot roller with GPS control;
- Trimming to shape using a total station grader with water cart support;
- Application of a surface choking layer (PAP 7) using chip spreaders x 2 with watercart support; and
- Completion of secondary compaction using a 2xPneumatic tyred roller (PTR)and 3 point steel roller.

The HiLab specification requires completion of primary compaction and trimming a maximum of two hours after hoeing as is the requirement of NZTA B/5 (modified pavements). However, the perceived stricter QA compliance requirements discussed earlier in this report have resulted in the Contractor taking a highly conservative approach to resourcing to ensure total compliance.

To provide some context, it is the view of the author that current labour and plant allowances to construct a HiLab pavement are significantly higher than those that would be allowed for when pricing a cement modified or foam bitumen pavement operation.

4.4 HiLab rates estimate

Gerhard Van Blerk of NZTA has provided a sample of recent HiLab tender and negotiated rates for projects associated with the Waikato Expressway. In addition to these rates the author has completed a detailed bottom up cost estimate for the HiLab supply and construction.

Table 5 below indicates the range of rates provided and the bottom up cost rate calculated. Full details of the cost estimate are included in Appendix A.

Layer description	HiLab contact rates range ($)	Hi Lab cost estimate from first principles ($)	Rates adopted for cost comparison ($), median
HiLab 65, 230mm	[redacted]		
HiLab 40, 200mm			

Table 5: Rates Estimate

Notes –

1. *Rates rounded to the nearest whole dollar.*
2. *Rates exclude GST.*
3. *HiLab contract rates based on recent tender rates and negotiated rates provided by NZTA.*
4. *All rates inclusive of 35% margin.*
5. *The HiLab cost estimate includes* s 9(2)(i) [redacted]

4.5 Rates for other pavement and surfacing components

Rates for other components of the estimates have been based on recent contract and sample rates provided by industry. A bottom up cost analysis of these components has not been completed as these rates are reasonably well established by industry. Cart distance for aggregate and surfacing material is likely to be similar to that assumed for the HiLab bottom up analysis although there may be some variation.

5. COST COMPARISON

Table 6 below summarises the cost of the options. The rates have been reported on a per m^2 basis with a percentage difference from the HiLab option also reported. Option 3b adopts a modulus at the top of the subgrade improvement layer of 150MPa.

Option 1 - HiLab	Option 2 - SAC w bound subbase	Option 3 - SAC w gran base	Option 3b - SAC w gran base over 150MPa SIL	Option 4 - FBS with modified subbase
s 9(2)(i) [redacted]				

Table 6: Cost Comparision

Notes on table

1. *All rates exclusive of GST.*
2. *The rates are based on large scale pavement construction (approx. 150,000m^2).*
3. *Rates do not include the cost of the SIL.*
4. *All rates inclusive of margin.*

6. CONCLUSIONS

Following initial trials on maintenance rehabilitation projects in the Waikato region HiLab is being constructed on three current stages of the Waikato Expressway. The pavement solution has been selected by NZTA as an alternative option to more established pavement treatments such as Structural AC or Foam Bitumen Stabilising.

A capital cost comparison of four alternative pavement configurations against HiLab has been completed. The summary results are shown in table 7 below: -

Option 1 - HiLab	Option 2 - SAC w bound subbase	Option 3 - SAC w gran base	Option 3b – SAC w gran base on 150MPa SIL	Option 4 - FBS with modified subbase
s 9(2)(i) [redacted]				

Table 7 : Capital Cost Comparision

The specification of the pavement layers influences the specification of the surfacings above. The HiLab and Foam Bitumen options require higher cost SMA/chipseal surfacings whilst the structural AC options are compatible with OGPA/tack coat surfacings.

In the case of the SAC options, the AC thickness required is sensitive to the underlying subgrade CBR adopted for design purposes. Subgrade design parameters adopted for this price comparison mirror those prescribed for the Huntly Bypass project. The adoption of a subgrade CBR 10/modulus 100MPa at the top of the 900mm subgrade improvement layer is considered conservative.

An alternative design, 3b, incorporates a subgrade modulus of 150MPa at the top of the SIL which the reflects the depth and quality of the material used in the SIL. This alternative provides the lowest cost SAC option. It comprises 30mm OGPA with tack coat over 180mm total depth AC over a 200mm M4 AP40 granular base over a 150MPa SIL.

It is the view of the author that HiLab costs are still evolving as suppliers better understand the following key factors:

- Construction methodology and resource (plant and labour) requirements. The current process is considered labour and plant intensive as crews focus on quality control during short duration high intensity work periods; and
- Aggregate production process and value of by product. Industry's understanding of actual production costs is still developing. Key considerations are frequency of batch nonconformance due to tighter specification controls and long term average value of by product generated from the HiLab operation.

The difference in cost between the options discussed in this report would likely vary beyond the figures shown in the table above on a specific project basis. Project variables would include:

- Bitumen cost fluctuation;
- Cart distance from aggregate supply sources;
- Cart distance from bitumen supply sources; and
- Individual Contractor capability and perceived risk of options.

In broad terms the HiLab and Foam Bitumen options have a comparable capital costs (less than 10% difference) whilst the structural AC options are in the region of 70% to 90% higher in cost than a HiLab pavement as a minimum.

APPENDIX A – HILAB DETAILED COST ESTIMATE

s 9(2)(i)

[redacted]

s 9(2)(i)

[redacted]