Review of State Highway Pavement Delivery

for

New Zealand Transport Agency

January 2020

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Disclaimer

Although every effort has been made to ensure the accuracy of the material and integrity of the content presented herein, the Reviewers accept no liability for any actions taken on the basis of the report or its contents.

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TERMS OF REFERENCE

The Terms of Reference for this Review is included in Appendix 1. Key requirements are summarised as follows;

Purpose

To review the current NZ Transport Agency end to end system delivery requirements for new pavement and rehabilitation construction and to assess these requirements in terms of best value for money to deliver on New Zealand's land transport objectives. The NZ Transport Agency's value for money investment principle is "the delivery of the right outcomes, at the right time, at the right cost and financed at the right level of risk".

This review will take a step back and see if there is anything more we could or should be doing to improve our (collective) performance. While the review is not expected to generate a fundamental change to systems and processes, there may still be opportunities to clarify and supplement existing pavement specifications, design processes and construction delivery.

Scope

The review should take a collaborative and beneficial approach that includes the following stages:

- Carry out interviews with a wide cross-section of industry.
- Establish and document the key process's and steps in our current pavement delivery system.
- Review these systems and processes against international best practice to determine what critical gaps exist in terms of achieving best value for money.
- Analyse the findings of the review ……. to determine if further changes to current practice are required.
- Provide recommendations and report back to the NZ Transport Agency and industry.

Scope Limitation

A background to the Review is pavement problems which are challenging the reliability on a number of recent capital projects. Whist the reviewers noted conversational points and examples relating to some of these projects, the Review was not scoped to determine the cause of any pavement problems for any particular project.

Industry Stakeholders

The Review conducted extensive feedback and comment from a wide range of industry representatives, all of whom have full involvement in pavement development, research, design, construction and quality compliance work.

Additionally, NZTA handed on a paper titled "Pavement Performance Position Paper" January 2019, from Civil Contractor New Zealand. This was considered as part of the Review.

Previous Pavement Reviews

As background information, an Executive Summary of a research project "Collecting Information on Pavement Quality Construction Projects" carried out by Chris Olsen Contracting in 2015, was made available to the reviewers (see Appendix 2). The purpose of the research was to identify pavement quality improvements of construction projects in New Zealand by using "case studies" to collect information on why pavement quality is variable.

The Reviewers understand that NZTA operational changes (e.g. Quality Right and others) in 2017 were developed in response to the Olsen research. This is relevant to this Review which appraises the “end to end system delivery” for new and rehabilitated pavements.

Conflicts of Interest

The reviewers both noted potential personal Conflicts of Interest. These were mitigated appropriately if and when conversation included the noted conflicts.

Lindsay Crossen

Personally, has very minor shareholding in Fulton Hogan Ltd from his past employment with that company. Lindsay is also a Life Member of CCNZ.

Mark Cruden

Through his consultancy business which includes pavement design;

1. Mackays to Peka Peka Root Cause assessment. Prepared a draft report for the Alliance's Professional Indemnity Insurer, QBE.
2. SH 73 Mingha Bluff to Rough Creek Realignment. Have been engaged by McConnell Group to provide preliminary advice as an independent expert into the suitability of the pavement design for the project.
3. Economic Analysis HILAB – NZTA have engaged Mark to conduct an economic analysis of HILAB costs relative to Foam Bitumen and Structural AC.

EXECUTIVE SUMMARY

Sound reliable road pavements are a critical element of road infrastructure. Pavement design and construction in New Zealand has evolved through sound practice complimented by research and innovation. Technical requirements are principally based on both AustRoads Guide and the supplementary New Zealand Pavement Design Guides (updated in 2017).

The general pavement requirement is; “design and durability performance shall be at least 25 years for all pavement structures” with lesser life for some surfacing treatments. The NZ Guide philosophy is; “to provide economic pavements using a risk based approach to choose the most appropriate pavement type and reduce risk of early failure”. This was intended to try to introduce more conservative options for higher traffic volumes – promoting modified pavements. Whilst this was well intentioned, perhaps we haven’t got the performance life expected from modified pavements with a return to unbound state happening rapidly, especially in certain climate / environments where moisture ingress is evident.

The pavement delivery industry has primarily been developed on unbound flexible pavements. These are more than fit for purpose and reliable on lower trafficked Regional State Highways, but, recent early failures highlight the need for robust structural pavements on key transportation routes to achieve design reliability.

Generally, “performance requirements” are not fully comprehended or appreciated by all deliverer’s in the industry. Expectations of reliability (>90%) and serviceability (over 25 years) are not well defined with measurable criteria. Performance Requirements should be clear and understood throughout the industry. Important criteria should articulate value for money, quantify life investment, serviceability expectations and factors of safety to ensure Reliability. Performance requirements should be measured over longer periods of time with financial tags to promote more conservative designs.

Review interviews, with some 30 stakeholders, concluded that design criteria is sound, although there are performance concerns with some of the newer pavement systems and their application in designs. Tensions have developed where designs have been optimized during procurement (influenced by commercial / funding aspects) resulting in Factors of Safety being compromised.

The stakeholders highlighted a number of technical concerns which need review and refinement to better inform design applications, construction quality and conformance testing. Pavement design is based on mechanistic–empirical analysis which is sensitive to compromise due to potential variability in both aggregate qualities and construction methodology.

Procurement for construction introduces performance orientated commercial contracts and thus designs optimization. Construction continuously provides challenge and variability to full achievement of design aspirations. Moving forward, it is critical that procurement and construction aspire to quality outputs to meet design and reliability expectations, corresponding to relevant factors of safety. Innovation and value for money considerations should focus on productivity and quality, rather than refinement and alternative designs.

The Agency’s implementation of Quality Right and Principal led Project Management is a sound initiative. Its extension for wider inclusion of NOC contracts is advocated. Quality Right will most benefit pavement delivery if it is extended in scope as an assurance driver, complimented by mitigated risk evaluation, for end to end process total delivery (i.e. design initiation to construction completion).

Pavement Reliability (an investment for 25 years) requires robust attention throughout the whole delivery process to ensure all phases are in balance and the built outcome is assured to realise high probability expectation relative Road Categories and transportation routes.

Pavements are the Agency's second rank depreciable asset and the Agency is a lead authority, technically, in the pavement industry. As such, there are a number of strategic considerations which are complimentary to pavement delivery;

- Through technical guidance and standards, the Agency can contribute to supporting its commercial delivery partners to lift performance and sustain skills and capability of people working in the industry.

- As a large user of aggregates, support sustainable resources for quality aggregates within efficient transportation of construction localities.

- It is likely that revised pavement risk/reliability criteria may have cost implications for more robust pavements and thus investment consequences for wider NZTA programmers.

- NZTA is the recognized leader and expert for pavements in New Zealand. To deliver effective leadership functions, it is desirable for the Agency to invest, organize and operate, in collaboration with Industry, to provide best effect to its leadership function.

The Terms of Reference called for "review of systems and processes against international best practice to determine what critical gaps exist in terms of value for money". The Review has regard for Austroads "Guide to Pavement Technology Part 2: Pavement Structural Design (2017)" and also "A Review of the Delivery of Quality Assurance in Road Construction" (Aug 2019). The NZ Guide to Pavement Structural Design is aligned to the Austroads Guide. The insights presented in the recent Review of Quality Assurance highlight many compromises identified in delivery, influenced by competitive contracting, time and community expectations. The learnings of QA Review and their incorporation into NZTA systems and processes is supported. Australian pavement construction is closely aligned in both type and technique with New Zealand.

The short timeframe for this Review, and the need to canvass a wide range of industry stakeholders, prevented more in depth "international best practice" comparison. NZTA may wish to canvas wider international best practice to supplement the findings of this Review.

This Review concludes that NZTA's organizational systems and processes for end to end pavements delivery are well formulated and sound. The Review findings highlight a number of matters where focused /refinement and discipline would improve design, delivery and reliability confidence. Whilst a large percentage of pavement kilometers are successfully constructed and rehabilitated annually, anecdotal feedback suggests appreciation and confidence of achieving desirable 25 year life reliability is marginal. Review of reliability/risk guidelines will thus have major influence in qualifying the Agency's value for money investment principles for pavements.

RECOMMENDATIONS

1. **Reliability/Risk Guidance**: The Agency reviews the NZ Guide to align performance expectations relative to Reliability Factor and Pavement Design Risks to better define pavement types most suited for sustainable transportation routes.

2. **Performance of Pavement Types**: Review and upgrade risk profiles and better define integrated performance criteria for current subgrade, pavement and surfacing compositions, especially, unbound, cement modified, foam bitumen and HILAB treatments and OGPA surfacing integrity, with specific consideration for environmental and climate, as well as traffic loading.

3. **Technical Refinement**: Address and refine technical matters of concerns from this Review which are implied to influence integrity in design, aggregates, construction practices and conformance testing,

   (Recommendations 2 & 3 should ideally be undertaken in collaboration with industry practitioners and the National Pavements Technical Group)

4. **Design Leadership**: The Reviewers are of mind that NZTA revert to industry expertise being engaged for design on capital projects in conjunction with robust longer term Performance Requirements, for benefits to commercial/performance procurement and sustaining industry expertise, collaboration and development.

5. **Procurement of Pavement Elements**: Review and refine procurement type and procedures to highlight the importance of pavement elements and encourage conforming quality delivery over the longer term.

6. **Quality Assurance:** Extend Quality Right processes, complemented with mitigated risk evaluation, as an end to end process through all pavement delivery phases and apply Quality Right as a highly preferred assurance discipline to include both new projects and rehabilitated pavements (i.e. NOC contracts).

7. **Quality Assurance**: Review and incorporate the findings of Austroads "Review of the Delivery of Quality Assurance in Road Construction (2019)" to strengthen and extend Quality Right with particular emphasis on real time QC information and control action..

8. **Industry Leadership**: Strategically, give importance to leadership for sustainable pavement industry through training, R&D, partnerships, economic aggregate availability, and personnel talent and construction capability.

9. **Industry Skills:** Facilitate ongoing training in the use of the current Guides and Standards to raise the holistic capability industry wide (i.e. design to construction) and encourage technology and innovative methodologies, which contribute to the opportunity of efficient construction control, quality and productivity and adherence to best practice.

   Note:
   These Recommendations should be read in conjunction with Findings tabulated throughout the report. The Findings signal matters which warrant operational consideration.

PAVEMENT REQUIREMENTS

This section relates to the Reviewer's understanding of cornerstones that influence NZTA current practice for pavement design and delivery.

Leadership Role

For many decades, NZTA, and its predecessors, have provided a leadership role for pavement technology and construction development and the provision of industry standards and specifications. This leadership was necessary, as a Government Agency, to establish and maintain pavement standards for Government funding/investment of the road network of New Zealand. State Highways are fully funded and local roads, whilst under the authority of Local Got, have substantial subsidy funding from the Land Transport Fund.

Leadership of technology and standards provides a benefit by demanding industry competence and performance. This has been particularly necessary as the industry has progressed through evolving change in procurement models since 1990 (i.e. introduction of the Transit NZ Act 1990) this change has caused progression from method prescription to performance outcome contracts, with corresponding competency and commercial influence on all industry participants.

To support its leadership status, NZTA has maintained a centre of pavement technical expertise, which has an active research and development programme and collaborative relationships with industry technical interest groups. Pavement standards and specifications are founded on these programmes and collaboration.

Pavement Policy

The New Zealand Transport Agency is an active member of Austroads and has decided to contribute to and utilise, wherever possible and practical, the practices of that organisation. Therefore, the NZ Transport Agency has adopted the Austroads pavement design procedures with variation as detailed in the 2017 ***New Zealand Guide to Pavement Structural Design*****.**

This Guide includes additional guidelines for the Engineer in applying the Austroads design procedures resulting from research and experience gained in New Zealand. The aim is to minimise confusion and promote consistency in design assumptions applied in New Zealand. This provides a consistent approach for taking full advantage of the knowledge and experience of the roading fraternities in both New Zealand and Australia.

Most of the state roading authorities in Australia have their own supplementary document to the Austroads Guide to integrate the standard design procedures with their unique material types and environmental conditions. The NZ Guide has been produced to facilitate the use of the Austroads document, ***Guide to Pavement Technology Part 2: Pavement Structural Design (Austroads 2017)*** in New Zealand by addressing the issues which are unique to New Zealand conditions.

Other State Roads Authorities in Australia place restrictions on the types of pavements that can be used in relation to traffic volumes. To maximise the use of economic pavements in New Zealand, a risk based approach has been introduced to choose the most appropriate pavement type to reduce the risk of early failure.

Pavement technology is continually being researched and changed. For this reason, both Austroads (2017) and the NZ Guide are intended to be living documents and will be regularly amended as new research findings come to light.

Technical Specifications

NZTA has developed, and continue to support, a wide range of Specifications. These cover technical design, materials, construction, surfacing and quality requirements. Specifications are updated and modified on a continuous basis based on research and development, in collaboration with wider industry stakeholders.

Generally, in New Zealand, pavement design and construction technology centres around flexible and semi rigid pavement structures, based on mechanistic- empirical design methods. Specifications covering this approach, developed over many decades, combine both technical science and method based approaches. Potential conflict, between technical performance outcomes and method prescribed compliance, was commented on by some stakeholders interviewed. The evolution of pavements is founded on technical/practical development and applied to a wide range of road pavement environments, therefore the specification mix is understandable, but possibly needs better rationalisation relevant to separate project applications.

Reliability Factors

An integral part of the pavement design process is an assessment of how well the outcome of the design – the constructed pavement – will perform.

It is unreasonable to expect that a pavement design process can guarantee, with absolute certainty that a subsequently-constructed pavement will perform to design expectations. The reasons for this are as follows:

- No design process perfectly models how a specific pavement will perform in a controlled environment with a specified traffic loading, let alone in its allotted environment when subjected to its actualtraffic.
- The design values chosen for material properties are, at best, gross simplifications of the complex and variable properties of pavement and subgrade materials.
- No construction process can produce a pavement in complete conformance with a design configuration, both in terms of layer thicknesses and (simplistic) material properties.

Because of this lack of certainty, an appropriate measure of the anticipated performance of the proposed pavement is its project reliability, which is defined as follows:

> *The Project Reliability is the probability that the pavement, when constructed to the chosen design, will outlast its design traffic before major rehabilitation is required. In regard to these reliability procedures, a project is defined as a portion from a uniformly designed and (nominally) uniformly constructed road pavement which is subsequently rehabilitated as an entity.*

The desired project reliability is chosen by the NZ Transport Agency or the road designer, depending on the project procurement process for any given project.

Table 1: Minimum project reliability as a function of road classification

One Network Road Classification[1]	Minimum Project Reliability (%)
National (High Volume)	97.5
National	95
Regional	90
Arterial	
Primary Collector	
Secondary Collector	
Access	80
Access (Low Volume)	

The desired project reliability is the chance that the pavement being considered will outlast its design traffic, assuming that:

- the pavement is designed in accordance with the procedures in the NZ Guide.
- the pavement is constructed in accordance with standard specifications
- the materials used meet standard specification requirements.

To achieve the desired project reliability in the mechanistic-empirical design of flexible pavements, it is necessary to use an appropriate performance relationship to estimate allowable loading from the calculated strains induced by the design traffic axles for each of three distress modes. For asphalt fatigue and cemented materials fatigue, Reliability Factors (RF) is used in the performance relationships appropriate to the desired project reliability. The performance relationship for rutting and shape loss is derived from the empirical design chart for unbound granular materials with thin bituminous surfacing. (Austroads and NZTA Design Guides provide relevant factors).

Design Guidelines

The pavement type should be selected to ensure a low risk of premature distress and major rehabilitation occurring before the end of the design life. For each pavement type the risk of premature distress can be reduced by implementing options for best practice as detailed in the Guide.

Pavement design is a risk-based process. In this context, risk is defined as being equal to the probability of failure multiplied by the consequence of that failure. For a particular site, the consequence of premature failure cannot be easily changed. Risk can therefore only be managed by reducing the probability of failure. This is achieved by accurate characterisation of material properties, adopting lower risk pavement designs and a focused attention on the quality of the construction process.

At the same time, however, the One Network Road Classification needs to be considered to ensure that the level of risk adopted is appropriate. For example, the use of marginal materials with higher shearing potential may be appropriate on lower classification roads. The intent is to assist designers to appropriately manage the risk of premature pavement failures in New Zealand and, in particular, minimise the risk of failure through informed design.

Assuming appropriate material characterisation and construction methodology the relative performance risk profiles of typical pavement configurations are detailed in Table 2.

Table 2; Risk of failure for pavement types

25 year design traffic volume (ESAs)	Less than 5×10^6	Between 5×10^6 and 1×10^7	Between 1×10^7 to 5×10^7	Greater than 5×10^7
Continuously Reinforced Concrete Pavement	**Unlikely to be economic**	**Unlikely to be economic**	**Unlikely to be economic**	**Low risk**
Structural Asphalt	**Unlikely to be economic**	**Unlikely to be economic**	**Low risk**	**Low risk**
Modified aggregate overlay basecourse and bound subbase	**Unlikely to be economic**	**Low risk**	**Low risk**	**Medium risk**
Foamed bitumen basecourse	**Low risk**	**Low risk**	**Low risk**	**Medium risk**
Modified aggregate base only	**Low risk**	**Low risk**	**Medium risk**	**High risk**
Unbound aggregate overlay	**Low risk**	**Medium risk**	**High risk**	**High risk**

The final pavement type may be restricted by financial constraints, although for a high profile pavement like an expressway or urban motorway a medium or higher level of risk must be noted in the design, as it may politically be unacceptable. The NZ Transport Agency's Risk Management Process Manual was followed to determine a starting point for designers in choosing the most appropriate pavement type. The final choice of pavement type requires designers to assess pavement type options as per the NZTA Risk Management Process Manual along with the calculation of Net Present Value (NPV) of whole of life costs (includes road user travel delays due to maintenance, capital and road maintenance costs).

Project Requirements

For each capital works project, specific Minimum Requirements (for D&C contracts) or Principal's Requirements (for collaborative ECI/alliance contracts) are developed and included in the Request for Proposal (RFP).

These requirements relate to the importance, environment and characteristics for the highway as they govern the desired performance and design life. The document is very detailed and encompasses all aspects for design, construction, materials and surfacing. Most importantly, the requirements state design life and durability performance expectations for the road pavement and the basis for technical design and contraction to achieve these based on industry best practice.

Selected General Requirements from the “requirements” are:

- *The design life and durability performance shall be at least 25 years for all pavement structures, 10 years for asphalt surfacing, and 20 years for Epoxy Modified Open Graded Porous Asphalt (EMOGPA). Chip seal surfaces shall meet the requirements of TNZ P/4 and P/17 (refer to Appendix A1 for Pavement Surfacing).*

- *Pavement design for the expressway shall be carried out in accordance with AP-G17/04 AUSTROADS “Pavement Design: A Guide to the Structural Design of Road Pavements” 2004, and the “Transit” New Zealand (TNZ) Supplement 2007. The Contractor shall use TNZ or NZTA Specifications for materials and construction, as required.*

- *Local road pavements shall comply with the local Council’s Codes of Practice, except where varied by these Principal’s Requirements.*

- *The basis for the pavement design shall be: the provided traffic design loading (DESA); and the subgrade CBR, as determined by the Contractor’s Designer (from their assessment of the geotechnical report, supplied subgrade test data, any additional testing, and calculated using the Austroads Pavement Design Guide.*

- *The Contractor shall provide a Peer Review, in terms of IPENZ Practice Note No. 2, of the Design, the Specification, and the Quality Plan. This shall be carried out by an independent Chartered Professional Engineer (Reviewer) suitably experienced in the design of state highway pavements.*

- *A copy of the Pavement and Surfacing Design, the Specification, the Quality Plan and the Reviewer’s Report shall be provided to the Engineer for evaluation and comment.*

An extensive schedule of performance requirements for expected constructed pavement outcomes is provided – including specified methods of testing and measurement for compliance testing. For assessment purposes, pavements will be divided into lots no greater than 200m or 1000 m^3 in volume.

Current NZTA Practice

D&C Capital Projects	From July 2017, NZTA provides a fully prescribed design for pavements in each D&C contract RFP. Tenderers may submit improvements to the design (related to material properties and/or construction technique).
ECI & Alliance Capital Projects	Design of pavements is provided by the Non Owner Proponents.
Network Outcome Contracts (NOC)	In these contracts, pavement rehabilitation design is the responsibility of the contractor and subject to NZTA review and approve.

Quality Right

In 2017, NZTA established a project “Quality Right – No Defects” with a focus on improving pavement quality. The project has been implemented and has four major themes:

1. Quality Management on Site
    a. Minimum Requirements to be included in the Quality Management Plans, (updated Spec Z/1).
    b. Minimum Standards for inspection, sampling and testing including Random Verification Tests and Hold Points during construction. (Updated Spec Z/8).
    c. Focus on identification of non-conformance, response and treatment and retention and storage of quality test data.

    d. Monthly quality meetings to discuss previous month's progress, matters of surveillance, results from analysis of rest data including non-compliance and corrective actions.

2. Tender Documentation and Contract Specifications
    a. More prescriptive pavement options
    b. Inclusion for Quality Management in contract price schedules
    c. Requirement to scope MSQA elements.
3. Changes to Contract Documents
    a. All changes to designs and construction standards implemented during a project are to be fully documented and be available for review.
4. Resource and Skills
    a. Provision of a Principal's site representative to provide surveillance and analysis of all data.
    b. Require the Principal's Agent to be experienced and qualified in pavement construction (new role for Principal's Site Representative had been introduced).

In new works projects, Quality Assurance is the responsibility of the Contractor, supported by project management verification and observation by the Principal's Agent. Additionally, necessary design and construction compliance documentation is committed by Designers and Constructors.

The introduction of Quality Right is a step by NZTA to reinforce disciplines and strengthen the Principal's assurance that quality pavements are being built as designed.

FINDINGS FROM THE REVIEW

The next six Sections of this report collect and summarizes matters collaborated with Industry Stakeholders on phases and aspects of pavement delivery.

Principally, collaboration loosely related to five themed questions.

Question 1

Are the performance requirements for new and rehabilitated pavements clearly defined, articulated and understood by all? (i.e. Reliability; Value for Money; Life Investment; Serviceability Factors)

Question 2

Are design parameters and guidelines fit for purpose to provide expected performance reliability of high probability?

Question 3

Do procurement and construction practices provide pavement outcomes that reflect design expectations and performance reliability?

Question 4

Does Quality Right reflect the necessary quality assurance and risk mitigation sufficient to influence built pavement performance sustainability.

Question 5

What other factors strategically impact on the provision of road pavement delivery?

- Skills and capabilities in the industry
- Aggregate resources to sustain the network
- Affordability for high reliability performance
- Leadership of standards and practices.

DESIGN

Design Guidelines

Through leadership by NZTA (and its predecessors), there has been a long term close association with AustRoads and alignment with their well-developed Pavement Guidelines. These Guidelines, together with New Zealand customized NZ Guidelines; provide a cornerstone for best practice pavement design and configuration. In New Zealand, the predominant pavement configuration has been low cost thin surfacing unbound pavements (which have provided good solution and service for Regional roads). Modified base and subbase layers have been developed and more use of structural pavements and asphalt and OGPA surfacing has evolved.

The Guides are guidelines only and highlight that a pavement configuration must consider all aspects of design, construction and maintenance to achieve high Reliability expectations. The Guides are NOT Codes of Practice or Design Rules. Experienced designer inputs into designs are necessary. This point was universally reinforced by the more experienced designers interviewed.

Since updating in 2017, the NZ Guide has been informed to the industry through workshops. Many stakeholders (other than knowledgeable designers) appeared not conversant with the Guide, so more exposure and training is desirable. To understand the sensitivities in pavements at time of construction, project manager, quality technician and construction supervisor understanding of the Guide and technical criteria is highly desirable.

Findings;

1. *Austroads and NZ Guides are well developed and extensively used (as guidelines – not COPs) to design pavements throughout the industry.*

2. *Recent (2017) Guidelines were workshopped to the industry. More knowledge transfer and personnel development is highly desirable.*

Design is Risk Based

Generally, there was confidence expressed by pavement designers that the Guides supported by professional geotechnical and physical analysis, can provide the Reliability expectations. The consensus, however, was levels of risk manipulated by commercial and funding factors caused serious tensions and thus compromised potential Reliability. Both these factors demand refinement of designs to optimize for cost preferences. Procurement tensions and Value for Money challenges have tended to minimize pavements without appreciation of the elevations in risk.

The review questioned stakeholders on performance expectations for the headline General Requirements;

> *The design life and durability performance shall be at least 25 years for all pavement structures, 10 years for asphalt surfacing, and 20 years for Epoxy Modified Open Graded Porous Asphalt (EMOGPA). Chip seal surfaces shall meet the requirements of TNZ P/4 and P/17 (refer to Appendix A1 for Pavement Surfacing).*

Responses were not conclusive or concise. Reference was made to AustRoads criteria for rutting and shears failures. For the NOC contracts, a two year rutting criteria of <=8mm applies. The review concludes that design life and durability performance is highly problematic due to a complex matrix of risk factors and unclear conformance criteria.

It remains a fine balance of judgement between Reliability, probability and pricing. Pavement lifetime maintenance appears not to be a serious influence and consequences of early failures do not attract sufficient appreciation of the potential risk. As highlighted in this report, construction quality shortcomings are not sufficiently appreciated and priced as risk contributions at the time of design and project award/funding approval.

A primary guideline (customised in the NZ Guide) is the risk relationship between 25 year ESA and typical pavement configurations. The relationship highlighted medium and high risk for most base and subbase configurations of pavements for greater than $2x10^7$ ESAs. Stakeholder concerns universally expressed inadequacy with such configurations in light of failures over the past decade. The Guide table appears to be influences by “financial restraints”. Reconsideration of risk modelling is desirable to better emphasize on technical criteria which is fit for purpose to better ensure high Reliability and minimized consequence due to serviceability compromise on high volume roads.

Environmental/climatic conditions do not currently influence treatment selection and design heavily and this is a significant shortcoming of the current guides. A more formal approach to considering these factors would be beneficial.

Findings;

1. *Current Practice - design is Principal led for capital projects and Contractor led for NOCs, signaling risk responsibility is based on who leads the design.*

2. *There is inconsistent risk appreciation and there needs to be a better defined risk management process at the design phase when pavement optimization occurs.*

3. *NZTA needs to better articulate performance expectations (including measurement over time) relative to prescribed Design Life of 25 years and the associated anticipated pavement maintenance regime that will typically apply over the design life term.*

    a. *Better define performance expectations for different pavement categories, especially unbound and cement modified pavement layers.*
    b. *Review and update risk profiles of current subgrade, pavement and surfacing compositions.*
    c. *Define better guidance around drainage and subgrade improvements.*

4. *Since mandating that NZTA designers will provide full pavement designs for capital projects, significant robustness in strength in pavement layers has been added and construction variations remain significant. The Reviewers are of mind that industry expertise should still be engaged for new pavement design in conjunction with robust longer term Performance Requirements, for benefits to commercial and performance procurement and sustaining industry expertise, collaboration and development.*

5. *Procurement drivers (VfM and commercial tensions) have trended to minimize pavements with potential change in Reliability risk not being appreciated.*

6. *A more formal approach to considering environmental /climate and construction challenges at time of design are desirable.*

Building the Design

It is evident that designers rely on Standard Specifications to formulate technical and construction criteria for their designs. This is sensible considering the familiar use of Standard Specifications by the construction industry.

It is likely that pavement configurations will be optimized thus inclusive of risk. It is important that designers establish and communicate risk sensitivities that the contractor should mitigate, including provision of quality plans and key observations and hold points especially where requirements deviate from or exceed standard specification requirements. The designer should also undertake construction observation and quality collaboration so that final completion accreditation is executable.

Findings;

1. *Design specified ITP/QA requirements for construction are essential to compliment all pavement design.*

Influences in Pavement Failures

As the review progressed, a number of technical deficiency themes became apparent. These are simply recorded in this review and need further in-depth evaluation to determine merit of the deficiency and a plan forward to better understand and develop resolution to give confident guidelines of specification change. Variability in constructed basecourse properties; density, total voids appear to correlate with rutting and shear failures in modified and unbound basecourse layers.

- Variability in constructed basecourse properties; density, total voids appear to correlate with rutting and shear failures in modified and unbound basecourse layers.
- Pavement waterproofing failures appear to correlate with rutting/shear failures together with low resilience breakdown of thin seal coats (and OGPA environmental surfacing) over modified pavements.
- Subgrade layer improvements and effective underdrainage are an important investment consideration in capital works.
- Managing the elimination of water from pavement structures is a design priority for all designers interviewed (but is an obvious catalyst of failures) and a refocus on this area is desirable.

Technical Concerns

The following technical concerns became apparent as Stakeholder interviews progressed.

a. Australian practice and recent NZ research potentially indicate rutting incidence is reduced if denser basecourse grading is used as an alternative to M4 Spec grading with ‘free draining’ capability.

b. Medium to long term performance of modified basecourses (and their incorporation to provide initial strength and reduce moisture sensitivity) may be an issue based on recent research in the field

c. HiLAB basecourse pavements have supply and construction complexities which may adversely affect reliability integrity, risk and economic viability. They do not yet have an established long term performance history.

d. Comparative risk relativities for basecourse types influencing Reliability Factor. Further refinement of alternative basecourse properties may help mitigate risk e.g. foam bitumen versus cement modified.

e. OGPA surfacing, and its endurance and compatibility with thin seal surfacing on modified pavements, appears to be a reliability risk.

Findings:

2. *Lessons learnt from early pavement failures, together with the “technical concerns” require a project to review, develop and communicate for correction and leadership guidance.*

3. *The Reviewers suggest NZTA works collaboratively with the National Pavement Technical Group (representing industry) to plan a project to address these technical concerns, as a priority.*

PROCUREMENT

Procurement Evolution

NZTA has well-established procurement models lead by experienced managers. Capital projects range from lump sum through to various iterations of Design & Construct, Early Contractor Involvement and Alliance procurement. For highway networks, long-term Network Outcome Contracts (NOC) is in the early stages of their second iteration. NOC's have significant emphasis on pavements, their maintenance, rehabilitation and outcomes representing safety, serviceability and sustainability.

Dealing specifically with pavements, new pavement projects previously had Minimum and/or Principal Requirements prescribing pavement performance standards. Since July 2017, operational practice has been to fully prescribe a pavement design. In the procurement phase, this pavement is priced inclusive in the tender. There is anecdotal information that Principal Specified Designs on current contracts are attracting appreciable variations. This highlights a defined risk transfer to NZTA relative to the policy change.

Findings;

1. *Evolution of procurement types has introduced a focus on performance delivery and commercial outcomes (i.e. D&C, ECI, Alliance)*
2. *Generally, outcomes have delivered some innovation, in the form of modified pavement types, but mostly resulted in minimization of pavements for commercial reasons.*

Value for Money Pricing

During procurement, Value for Money (VFM) initiatives are encouraged by NZTA. Historically, for pavement elements, this has attracted efficiencies being offered by contractors, which effectively minimised pavement layers, or alternative construction compositions to suit available aggregates or construction methodologies. Of significance, VFM aspirations can sometimes overlook balanced quality control and risk management:

- Pavement design modifications compromise/ marginalise risk of pavement failure;
- Pavement and surfacing selections compromise risk of compatibility;
- Pavement materials are less durable to traffic wheel loading, even when modified or have moisture presence

Value for money – 'accepting the complying best priced pavement'. There does not seem to be any criteria around value trade-offs to risk or resilience in determination of a 'complying' pavement. Procurement managers suggest NPV evaluations are used to compare options, but construction cost dominates therefore best price is favoured.

Since mandating that NZTA designers will provide full pavement designs for capital projects, significant robustness in strength in pavement layers has been added and construction variations remain significant. The Reviewers are of mind that industry expertise should still be engaged for new pavement design in conjunction with robust longer term Performance Requirements, for benefits to commercial and performance procurement and sustaining industry expertise, collaboration and development.

Findings;

1. *Value for Money considerations (at procurement) are heavily influences by NPV/WoL evaluations and lesser due to risk of failure and reliability reduction – which have intangibles which are difficult to value and appreciate.*
2. *Value for Money aspirations in pavement elements may skew risk balance in the project (i.e. risks associated with pavements is higher than environmental, structures, drainage, etc) risks. Cost savings from pavement optimization are lower than other elements and often, may not be significant to the total project value.*

3. *The Reviewers are of mind that industry expertise should still be engaged for new pavement design in conjunction with robust longer term Performance Requirements, for benefits to commercial and performance procurement and sustaining industry expertise, collaboration and development.*

Pavement Optimisation

Most procurement processes include a milestone for design alignment and challenge to scope and technical metrics. This is important for pavements to ensure correct understanding and application of the risk modified mechanistic – empirical design approach is applied.

This challenge will ensure technical values are not compromised and that commercial gains are genuine. Expert technical pavement personnel should be included in all challenge events. Contractors should have expert design involvement to guide design optimisation which is committed to in procurement, and correspondingly be aware of Performance requirement they are committing to deliver.

In the competitive contracting environment, there is pressure on contractors and subcontractors to win projects. Quality is at risk of being compromised to deliver projects on time, budget and also meet high levels of client and community expectations, Procurement and construction must deliver pavements that are built to achieve design performance expectations and extending duration of performance requirements will lead to more robust designs and construction quality conformance.

Findings;

1. *Technical challenge and risk evaluation (relative to pavement elements) appear variable during the procurement process.*

2. *Early alignment with preferred pavement configurations may not be relevant to Road Category and the risk of failure may not be fully appreciated and mitigated in later stages of procurement and construction.*

3. *Extending the timeframe for contract performance compliance will be a way to divest design responsibility to the industry*

Constructability Considerations

Post procurement, any adjustment to pavement designs, promoted by subgrade or material variables, will again require pavement expert overview before construction. In the first instance, changes should be designer led but Principal awareness is essential to ensure Reliability projection is not compromised. It is also important that the procurement process critically assesses contractor resources, capability and track record to deliver quality pavement construction.

Findings;

1. *Materials, methodology and construction capability for pavements – to successfully build a high quality design, these require better scrutiny and qualification in the procurement.*

2. *Quality Assurance planning and processes for pavements should be a scored attribute for procurement.*

The procurement phase is a critical element in the end to end pavement design to delivery process. This is because professionals and personnel can be discontinued for the design and project delivery management phase.

CONSTRUCTION

Construction Industry Capability

Construction of pavements, principally for rehabilitation, but also for new pavement projects, is a capability which all road contractors have invested in and sustained as a key capability of their businesses. Stakeholder feedback was confident that the necessary capability and resources can be sustained.

There is considerable capability NZ wide to construct unbound pavements, this being the predominant pavement construction on Regional roads. During the past two decades, resources and capability have been developed to provide competency in cement, lime and bitumen modified pavements as well as structural asphaltic concrete pavements. There is only limited capability to construct concrete pavements and HiLAB is an emerging technology with a specific construction method requirement. There is a very good level of competency to construct surfacing of chip seal, OGPA, asphalt and modified special surfacing.

Skills and competency advancement has been contractor generated as innovation in modified pavements construction evolved. Leading contractors have training / experience programmers in place although this is challenged by employment churn. Stakeholders emphasized the developments of technology to aid construction, with examples being electronic geometric control during trimming and compaction monitoring during rolling. Methodologies such as paver laying, stabilizing, aggregate mixing off site and similar, are increasing in occurrence as constructors seek better control and quality together with shorter duration construction disruption on live road situations.

Findings;

1. *Industry has long experience of well-developed construction methodologies for most pavement types (i.e. AC, modified and unbound basecourses, unbound, modified and bound subbases, drainage, etc.) with cornerstone Standard Specifications for materials and construction methods. HiLAB is an emerging technology, with specific construction methodology requirements.*

2. *Contractor resourcing for pavement construction*
   a. *Contractor sustainable training/experience regime presents challenges.*
   b. *GPS, compaction and similar technologies are evolving and employed well.*

Pavement Constructability

For pavement Reliability, an integral part of pavement design is consideration of how well the constructed pavement will perform. No construction process can produce a pavement in complete conformance with design configurations, pavement thickness, compaction and (simplistic) material properties.

There are numerous pavement designs and rehabilitation treatments which, if constructed under ideal conditions, may meet the design objectives. However, if they are constructed under less than ideal conditions, then the pavement will be susceptible to premature distress. Therefore, as the pavement is susceptible to matters relating to conditions at time of construction, there is a significant risk to lower Reliability.

Conditions which could influence less than ideal construction conditions are;

- Limitations due to constructing in live lanes and out of season construction.
- Design sensitivities for layer stiffness, moisture, modification mixes.
- Use of variable quality or lower grade materials to that assumed at design.
- Choice of methodology to mitigate the construction ‘environment’ (use of paver lay, modification of aggregates, etc.) to overcome quality sensitivities.
- Constructible risks relative to various pavement types and the climatic environment.

Generally, pavement designers have indicated that designs include robustness to compensate for moderate 'environmental' influences but intervention and variation should be practiced as a quality measure to mitigate Reliability risks being compromised.

The construction industry develops its pavements capability working with reference to many fine Standard Specifications which embody both technical and method criteria. Also, construction techniques are developed by experience building with aggregates common to the geology of the site locality. Both these factors can be sensitive to change and thus the construction quality. Misalignment of Standard Specifications or material properties to design expectations, or inadequate design / constructor instruction and collaboration can lead to less than ideal outcomes.

Findings;

1. *Site conditions including climatic influences will manifest variability in pavements and potentially present a risk to pavement Reliability through premature distress and defects.*

2. *Construction competencies are sound but contractor understanding of key risks, design sensitivities and 'site adjustments' could be better appreciated.*

3. *'well built' is more important than 'well designed' to contribute to reliability*

Quality Assured Construction

The risks for variable outcomes during pavement construction are extensive. Stakeholder feedback universally conveyed the sensitivity of quality variability during the building phase and challenges the constructor faces.

NZTA procurement criteria require Contractors to be Quality Assurance accredited. Further ITPs and Project Quality Plans are a prerequisite before construction commences. In 2015, a study commissioned by NZTA, reported a survey "where parties involved in D&C contracts rated their performance";

- Achieving the project Principal Requirements as an average of 8 out of 10.
- Achieving their definition of quality as an average of 6 out of 10
- The quality of the finished product was rated somewhat lower.

Whilst stakeholder feedback in this Review did not survey to the same rigor, feedback conveyed similar concerns and acknowledgement that better and more consistent quality outcomes are highly desirable for the industry as a whole.

NZTA has, since the 2015 study, introduced the "Quality Right – No Defects" programme to ensure better Quality Assurance during construction. This has been introduced into capital projects but is not in the NOC contracts (which have specific QA and control requirements embodied in the contracts). Correspondingly, NZTA has increased the level of direct Principal Project Management and observation of the quality testing on capital projects.

QA and QC, and relevant Testing, will be more extensively discussed under the Quality section of this report.

It is important, however, that quality observation and conformance correction is managed 'real time' to avoid built in non-conformances. Regular comment by stakeholder's highlighted frustration that testing was not keeping pace with construction and "late" test results complicated construction progress. Further, sharing of quality test information with designers, suppliers, Principal and project managers was regularly not in the realm of "leading indicator quality assurance" where quality issues and trends would be monitored and mitigated as necessary. This aspect should be universally addressed to create leadership features in any QA process and QC Plans.

Findings;

1. *Quality Right has been implemented on New Works Projects, although, further implementation and operational discipline, and extension to NOC contracts, is desirable.*

2. *Quality Assurance shortcomings are evident in the construction phase and appear to affect longer projects as much, if not more, than smaller projects.*
    a. *Appropriate testing nominated for design outcomes.*
    b. *Real time QA – cloud base information sharing.*
    c. *Effective timely mitigation of non-conformances.*
    d. *MSQA independence and ability to influence and resolve variables.*

3. *Contractor resourcing for pavement construction*
    a. *Better management and information sharing of QA process.*
    b. *Proactive planning for materials, construction and risk mitigation.*

4. *Principal focused Project Management has been upgraded, funded and implemented and contracted MSQA requirements are well defined.*

QUALITY

Implementation of QUALITY RIGHT

As has been highlighted in the Construction section of this report, quality assurance and control functions heavily influence achievement of successful pavement construction and high probability Reliability. After a study in 2015, in 2017 NZTA introduced and progressively implemented "Quality Right – No Defects" programmers. At this point in time, the programme is only partly embedded.

Stakeholders generally agreed that there is considerable room for advancement in quality processes and disciplines for the benefit of assured pavement construction and Reliability. Leadership by NZTA to extend Quality Right induction and implementation across the whole spectrum of pavement construction is supported. Quality Right, whilst providing for improved active observation and compliance testing by Principal's project managers (or agents) still places emphasis on designers and contractors to have robust QA systems and Quality Plans for the project which provide both leadership and conformance accreditation to the pavements as constructed.

It is unclear to the Reviewers the extent that Quality Right processes are providing assurance and controls for the Principal during the pre-design, design and procurement phases (when optmisation and refinement occurs). In these phases of pavement delivery, many interpretations and risk options are encountered. It is noted that Peer Review in utilized for new pavements on projects involving collaborative contract types. Extension of Quality Right requirements to include suitable accreditation and review steps (i.e. similar to Practice Standard 1 to 4 format accreditation) is logical to improve assurance for the Principal and provide expectation for successful post construction reliability.

Findings;

1. *Quality Right – No Defects, with a focus on improving pavement construction, is an admirable initiative. It is built on quality assurance, design conformance and effective project management to provide measurable discipline to achievement of outcomes.*

2. *The review identified variable uptake and application and suggests further organizational induction and application to provide effective assurance of outcomes to the Principal (NZTA).*

3. *Generally, stakeholders comment expressed concern about consistency of construction quality processes /mitigation and conveyed a desire that improvement is necessary.*

4. *Extension of Quality Right processes into the design and procurement phases would assist assurance for the Principal.*

Project Management

It is pleasing to see a step up in the role of Principal Project Manager and specific funding for project management and independent testing activity. Effective project management is best delivered in a leadership style which fosters a collaborative relationship between the principal, designer and contractor. The position brief for Project Managers clearly accents key duties; however, these need to be supported by ITP's and Quality Plans for each project.

The NOC's have quality requirements embedded in the contracts, but could possibly learn and develop from the Quality Right initiative to better assure pavement construction outcomes are a sound reflection of designs and maximize Reliability. One aspect of concern in the NOC's is, whilst the designs for rehabilitations are formally "approved" prior to construction (to support funding variations), there appears to be no formal "acceptance" of completed pavements. A construction report is provided by the contractor and this should be subject to an equivalent PS4 accreditation by the designer and an audit for quality conformance, before the pavement is accepted by NZTA as complete.

Findings;

1. *Project Delivery Management should be professional, collaborative and exhibit independence and be collaborative with mitigation for successful pavement outcomes.*

2. *NOC contracts would benefit from adoptions of Quality Right and formalized Completion acceptance criteria.*

Technical Requirements

In the Construction section, we highlighted the familiar use of Standard Specifications by contractors for pavement construction. Standard Specifications have been formulated over many years and should be regarded as best practice and technically sound. They are based on extensive “in practice” construction experience and monitoring and are complemented by research driven refinements.

There are three matters raised by stakeholders relative to some challenges Standard Specifications provide;

a. Predominantly for rehabilitation, the pavements industry has evolved using Standard Specifications to support simplistic design. These specifications are a mix of both technical criteria, which is supported by conformance testing, and methodology, (e.g. B Series specifications), which provide guidance for suppliers and constructors. Stakeholders concerns are that, as pavement designs become more refined, there is a developing mismatch between the technical criteria and method guideline. Precedence of criteria hierarchy is not always clear. When conformance differences become evident during construction, acceptance and/or resolution of defects requires “expert” intervention which is not readily available.

b. As more refined designs are now being used, it is highly important that simplistic technical requirements and sensitivities to Standard Specification criteria are adequately documented and communicated to construction teams. This will help ensure specific design expectations can be accommodated with minimal risk in the construction. It is desirable that designers provide specific quality testing and hold points for construction and also, to support their acceptance accreditation, they adequately observe construction and conformance test results.

c. A number of stakeholders expressed concern that Quality Right was extending the amount of testing. Further, there is strong opinion that testing and material properties assessment at the design stage are trending to represent a “laboratory environment” whereas it is more desirable tests represent the actual built “field environment”, as constructed. The “field environment” will provide qualififying representation in relation to design theory and expectations for pavement stiffness, strength and durability and thus probability for high Reliability.

Findings;

1. *Standard Specifications are a cornerstone of pavement materials and construction (and familiar to constructors). There should be robustness to ensure incorporation of designed prescribed specifications (beyond the standard requirements), sensitivities, or material characteristics are transferred for constructor awareness.*

2. *Refinement of pavement designs sometimes increases pressure to make marginal materials work. This is where quality control is critical to ensure designer aspirations. Conversely design must be realistic in terms of likely construction outcomes.*

There appears to be a real issue is that we are using laboratory tests such as RLT and ITS at the design stage to inform understanding of likely performance. The problem comes at construction time when these tests don't readily align with construction testing.

Whilst RLT testing provides some guidance on the likely rut resistance performance of an aggregate, it is not a guarantee of performance. Similarly the variation between laboratory ITS results during design and field results during construction make it problematic to understand performance outcomes of the constructed pavement.

Quality Effectiveness

The predominant feedback from stakeholders was comment on the ineffectiveness of Quality Assurance processes during the construction phase. During pavement construction, there are a multitude of conformance tests undertaken to measure compliance with various criteria. Many of these tests, particularly simple tests such as compaction meters, Clegg hammer, proof rolling and similar, provide guidance to construction that the global strengths are trending and progress with construction is reasonably assured. More sophisticated tests which require complex sampling and laboratory evaluation are more problematic to delays with results and potential disruption to construction progress.

A regular comment was test result information is not readily shared, thus not always available in real time for effective project management and/or designer scrutiny. This prevents effective identification of trends and compliances and the generation of mitigated solutions or remedy of defects. This aspect appears to prevail on larger projects where there would be an expectation of robust quality systems in practice.

For quality Right to be effective;

- There needs to be a transparency of the requirements in the quality test plan;
- That testing is tailored to effectively measure the constructed pavement relative to the design;
- The quality testing and observation data is shared to all parties in "real time", and;
- Regular scheduled (or triggered) collaboration occurs to address quality outcome trends, mitigation measures and/or remedial actions.

The objective of such management discipline is to improve quality consistency and Reliability. Quality meetings will ensure both Designer and Principal are able to observe progressive construction outcomes and respond in "real time" to support Reliability expectations.

Stakeholders also extensively commented on the challenges "environmental influences" present to construction and the compromise of risk management to overcome these. The risks likely to be presented should be mapped in the design and quality plans with suitable mitigations developed as part of construction planning. By addressing "environmental" risks early, construction solutions, methodologies and alternative pavement configurations may be incorporated to achieve the necessary Reliability.

Findings;

1. *Design and quality test plans should account, and provide tolerance accordingly, for likely site 'environmental' influences (i.e. live traffic, weather, material variability, etc.) which are potentially disruptive to construction. Risks may be mitigated by alternative pavement configuration.*

2. *Quality planning and project management should incorporate 'real time' test monitoring, information sharing and mitigation action to aspire to successful construction achievement.*

RISK

Delivery of pavements, both for new works and rehabilitations, is non exact engineering. This is due to the variability in subgrades, pavement materials, empirical mechanistic design philosophies, construction methods, site environmental factors and dynamic loading inflicted by heavy motor vehicles.

> *Risk can only be managed by reducing the probability of failure; by accurately characterising materials, adopting lower risk pavement designs and a focused attention on quality of the construction process.*

NZTA seeks, through this review, to scrutinize the 'end to end' delivery systems for new pavements and rehabilitations. Delivery best practice seeks to optimize pavements to achieve 'the best affordable pavement' for each project situation. A factor identified by this review is the level of risk and mitigation applied to selection, optimization and construction of pavements appears independent at each phase and does not have continuity in the end to end process.

Guidelines highlight design of pavements is a risk based approach. This is not disputed, however, the NZ Guide to Pavement Structural Design, whilst regularly signaling that the designer "consider the risks", provides very little explanation of risk level acceptability or scrutiny. Reliability Factors (probabilities) are specified by Road Category and Risk of Failure for pavement types relative to design traffic volumes, but these are global criteria. The Guide provides extensive "guidance" but it is left to the designer to assess and resolve the level of risk for the pavement as a whole and sensitivities to that risk.

Risk appreciation and mitigation was discussed with many stakeholders. Whilst most had an appreciation of risk in the phase of delivery they participated in, there did not appear to be an end to end continuity of risk appreciation and transfer. At each phase, risk is incorporated and it influences the outcome integrity. If there is no alignment – end to end – a risk mitigation assumption at optimization of the design or in procurement may be overlooked or not adequately addressed at construction. Progressive risk evaluation and appreciation should be aligned at all milestones as part of the quality assurance for the pavement; i.e. design approval, procurement award, material supply, and construction planning and completion acceptance.

Findings;

1. *The NZTA 'Current Process for Pavement Delivery' does not exhibit a visible continuity for risk awareness, transfer and mitigation throughout the entire process from pre-design, procurement and through to construction.*

2. *NZTA, to compliment Quality Right, should implement an 'end to end' pavement risk evaluation / mitigation process, which provides visible continuity through project phases and, importantly, is readily reviewable by expert practitioners.*

Headline Risks for Pavement Delivery

a. Road Category and options for pavement configuration that will provide high probability Reliability for the projected HV traffic usage.
b. Aggregate materials and supply that will be economically available for the project.
c. Subgrade conditions, strength and drainage and subgrade improvement investment.
d. The optimized structural pavement design for the works including a detailed risk evaluation and mitigation.
e. The optimized surfacing to provide resilient waterproofing and safe traffic wearability.
f. Independent Test Plans and Specifications provided for construction.
g. During procurement, expert challenge to design modifications related to resources, and/or VfM refinements
h. Contractor capability to construct well (resources, equipment and talent).
i. Environmental, traffic interference and climatic conditions during construction.
j. Contractor's QA Plan before construction commences.
k. During Construction, risk audit of Quality Right requirements (including designer observations, control testing, MSQA performance and mitigation of non-conformances).

NZTA AS OWNER/PRINCIPAL

Industry Leadership

Pavements, on State Highways, are NZTA's second largest depreciable asset by value (surpassed only by structures). As such, annual and long-term investment and operational funding must be accorded high economic priority. Equally important, pavements, as the transportation carriageway, must be safe, serviceable and sustainable. To satisfy these metrics, NZTA has clear whole of life maintenance practices and investment policies.

NZTA is well regarded as the leader in pavements technology and the source of highly developed Standards and Specifications. NZTA has well regarded guidelines and procurement models for the delivery and maintenance of pavements. NZTA's leadership is well supported by an industry which includes experienced researchers, designers and constructors.

The review identified a sound strategic hierarchy of expertise within NZTA, although some operational refinement may benefit overall effectiveness.

Findings;

1. *Pavements are NZTA's second most depreciable asset by asset value. Also, the road surface is most important to the road user for comfortable travel and road safety.*

2. *As a leader in the pavement industry, and Owner of high quality pavements, NZTA expertise in pavement technology, research, and procurement and construction quality is critical. NZTA should place a high priority on resourcing and/or procuring 'expert capability' to sustain this leadership function.*

3. *Better operational alignment of pavements expertise to be effective in all phases of design, procurement and delivery is desirable and the Pavement Expert Group (NZTA's in house pavement engineers) should have influence in all phases.*

4. *Since mandating that NZTA designers will provide full pavement designs for capital projects, significant robustness in strength in pavement layers has been added and construction variations remain significant. The Reviewers are of mind that industry expertise should still be engaged for design in conjunction with robust longer term Performance Requirements, for benefits to commercial and performance procurement and sustaining industry expertise, collaboration and development.*

Performance & Reliability

Premature pavement failures are unacceptable to everybody. Economic viability appears to dominate initial pavement selections and solutions as well as the provision of pavement maintenance strategies and practices. New Zealand pavements are characterised by a long adopted policy to maximise use of low cost, thin-surfaced unsound pavements.

The risk-based approach to choose pavement solutions needs to have a balanced technical/ economical approach, relative to the road usage and environmental factors presented in a project. The NZ Guide continues this philosophy to encourage designers to appropriately minimise the risk of failures through informed design, but may have an economic factor bias.

Findings;

1. *Reliability Factors, relative to road classification and pavement types, requires reconsideration and extension to include factors wider than just economics. "Financial constraints, political unacceptability,*

marginal materials with high shearing potential", are all factors which should not have a dominant influence.

2. *Performance Requirements should be clear and understood throughout industry. Important considerations should articulate value for money, quantify life investment and overview serviceability criteria and factors.*

Asset Condition

To provide safe, serviceable and sustainable pavements on the road network, adoption of well-founded whole of life principles, supported by operational maintenance and investment regimes, is a basic essential. Many stakeholders interviewed highlighted that:

- Many pavements both new and rehabilitated are being built too light;
- Rehabilitation activity is currently less than 1% of asset size;
- Repair techniques are minimised – 'cut down';
- WoL and Serviceability criteria are visibly stretched ;
- Some procurement drivers are influencing maintenance options;
- Traffic usage is underestimated.

Recent pavement rehabilitations, completed on the NOCs, appear more sustainable because;

- The existing pavements, generally, are in an overextended state leading to more robust renewal options;
- Rehab guides require prior investigation and qualification of root cause of failure and subsequent design solutions;
- New pavement rehabilitations configurations are lower risk.

In New Zealand the Transit Act 1990 transformed delivery of road pavement maintenance and construction. The past 30 years has seen the evolution of many contracting models to the state today where collaborative, performance outcome (NOC) regimes are universally used. The review received positive comments about NOC contracts from both NZTA and contracting stakeholders.

There does seem to be general concern however, that the principles and economics of Whole of Life maintenance regimes are not well understood across the industry. This primarily relates to timing, costs and effectiveness for interventions to maximise sustainable pavement serviceability. A challenge regularly mentioned was the influence of discount factor in NPV evaluations together with uncharacteristic and loaded treatment timings influencing solutions.

Findings:

1. *Stakeholders accented influences which heightened safety, serviceability and sustainability risk which can be addressed by NZTA through policy, programme and funding responsibilities.*

2. *NZTA's annual pavement rehabilitation is about 0.7% of the network length. There is advocacy for it to be in the order of 2.0% to sustain integrity and minimize excessive overextending of pavements.*

3. *NZTA should rationalise WoL principles and practices and challenge NPV sensitivities to ensure solution risk are minimised for best economic efficiency.*

Pavement Aggregate Resources

The road network uses considerable amounts of aggregate annually. NZTA, as steward for an extensive network of key routes, requires sound rock resource (manufactured into aggregate) for maintenance and construction programmes. Many stakeholders interviewed highlighted:

- Difficulty sustaining quarry activities due to RMA and comment influences;
- Some specification constraint on rock suitability from selected quarries;
- Project programming causing difficulty for the market to develop quarries to supply;
- Use of lower quality rock with selected modification (i.e. cement) may have some long-life quality challenges depending on site conditions.

Whilst concrete and asphalt demand quality rock for aggregates, pavements have been engineered to be built using well specified all-purpose aggregates. Also, quantities of road construction aggregates are significantly more than the premium aggregates, hence quarry efficiencies are balanced.

Two main issues have been highlighted that require consideration of NZTA as an infrastructure owner:

- Willingness or capability to influence Resource Planning to ensure quarry resource is reasonable available to economically supply best aggregate for road pavements;
- Forward programming and procurement with lead times sufficient for quarry development to supply large capital works with economic efficiency.

The quarry industry is fully market orientated, but has considerable RMA and development challenges which are counterproductive to NZTA's economic efficiency aspirations.

Findings;

1. *Quarry resources, for pavement aggregates, face development difficulties due to RMA challenges and disposal of lower quality overburden materials. NZTA networks are reliant on sound pavement aggregate supplies, within economic transportation distance. Long term planning and collaboration with aggregate suppliers should be a consideration in NZTA's strategy for economic road delivery.*

2. *Quarry aggregates have considerable rock variability and grading characteristics which challenge suppliers and contractors to achieve satisfactory pavements. Modern pavements require this prime resource to maximise Reliability probability.*

Quality and Risk Transparency

NZTA has proactively implemented Quality Right to provide assurance and controls through principally the construction phase when compromise of Owner and Designer expectations can manifest. This Review advocates Quality Right should also be fully employed as an assurance tool for the pre-design, design and procurement phases where optimisation and risk judgements are made.

The Risk Section of this report highlights a clear need for an effective end to end risk evaluation / mitigation system to provide leadership for expectations in reliability to be fully achieved. Such a risk system, working in tandem with Quality Right assurance processes would be a powerful tool to assure well designed and built reliable pavements.

SUMMARY OF REVIEW

Are the performance requirements for new and rehabilitated pavements clearly defined, articulated and understood by all? (i.e. Reliability; Value for Money; Life Investment; Serviceability Factors).

The general pavement requirement is; "a design and durability performance shall be at least 25 years for all pavement structures" with lesser life for some surfacing treatments. This requirement conflicts with the NZ Guide philosophy; "to maximize the use of economic pavements in NZ using a risk based approach to choose the most appropriate pavement type and reduce risk of early failure".

New Zealand pavement delivery industry has primarily been developed on unbound flexible pavements. These are more than fit for purpose and reliability on lower trafficked Regional State Highways, but recent early failures highlight the need for robust structural pavements on key transportation routes to achieve best reliability.

Generally, "performance requirements" are not fully comprehended or appreciated by all deliverer's in the industry. Expectations of reliability (>90%) and serviceability (over 25 years) are not well defined with measurable criteria.

Performance Requirements should be clear and understood throughout the industry. Important criteria should articulate value for money, quantify life investment, serviceability expectations factors of safety to ensure reliability.

Are design parameters and guidelines fit for purpose to provide expected performance reliability of high probability?

Generally, design criteria are sound, although there are some performance concerns with some of the newer pavement categories and their application in designs. Tensions have developed where designs have been optimized during procurement (influenced by commercial / funding aspects) resulting in Factors of Safety being reduced.

Performance expectations are not well articulated or measurable for both early and longer term life. Similarly, materials and construction variables have influence which compound reliability. The NZ Guide should be corrected to;

- Better articulate performance expectations (including measurement over time) relative to prescribed Design Life of 25 years and the associated anticipated pavement maintenance regime that will typically apply over the design life term.
- Better define performance expectations for different pavement categories, especially unbound and cement modified pavement layers.
- Review and update risk profiles of current subgrade, pavement and surfacing compositions.
- Better define guidance around drainage and subgrade improvements
- Extend Quality Right as an "end to end" process.

The further development of design guides and construction specifications should be completed in conjunction with industry. The National Pavements Technical Group provides an appropriate interface for this consultation.

Do procurement and construction practices provide pavement outcomes that reflect design expectations and performance reliability?

Investment constraints, and commercial/value for money performance orientated contracts, have driven optimization of pavement design. This has included minimalisation of pavement thickness and introduction of modified subbase and basecourse layers. Undoubtedly there have been cost savings in new and rehabilitated pavements, but, it is uncertain if lifelong investment has been truly economic. Another depreciating factor is road user economic impact due to early failures.

Construction has always been understood to provide challenge and variability to achievement of design aspirations. This can only be mitigated by employing robust quality assurance management. A compromising factor is construction contracts usually employ short term performance commitments (< 5 years) which bear no performance relativity to life reliability expectations for pavement performance.

Procurement and construction must deliver pavements that are built to achieve design performance expectations and extending duration of performance requirements will lead to more robust designs and construction quality conformance.

Does Quality Right reflect the necessary quality assurance and risk mitigation sufficient to influence built pavement performance sustainability.

Quality Right and associated Project Management process changes have been a good initiative to inject better assurance for NZTA, as Principal to delivery contracts and ultimate lifelong Owner of the new pavements. Quality Right, however, has only been implemented for new project pavements and benefits would accrue if it was universal across all pavement construction and rehabilitation.

Quality Right appears to be limited in extent to the construction phase of delivery. It is highly desirable that Quality Right be extended to be an effective assurance system, complimented by an effective risk/mitigation evaluation, for end to end application.

The purpose of Quality Right is to assure the Principal that the constructed pavement is fit for purpose and has a high probability of Reliability.

What other factors strategically impact on the provision of road pavement delivery?

These points directly relate to pavements having a status as NZTA's second ranked depreciable asset.

- **Skills and capabilities in the industry**
  Whilst it is Industry's (design and construction) own responsibility to adequately resource their businesses, NZTA, through its leadership role has influence. R&D, knowledge dissemination, procurement evaluation & feedback, quality observation, are aspects where NZTA leadership can support a talented pavement delivery industry. Encouraging technology and innovative methodologies, which contribute to efficient construction control, quality and productivity is an opportunity. Ongoing training in the use of the current Guides and Standards will raise the capability industry wide and is essential to counter churn of staff in the industry.

- **Aggregate resources to sustain the network**
  With a primary need for construction aggregates, NZTA (together with other road authorities) strategically requires vibrant quarry industries that can provide quality aggregates within efficient transportation of

network construction sites. NZTA's interest in this primary resource should be a strategic counterbalance to RM Act challenges faced by Industry.

- **Affordability for high reliability performance**
  The prime tension for provision of pavements of the desired Reliability is the availability of funding. This Review has highlighted that reconsideration of risk for some pavement types and situations is desirable. It is likely that revised pavement risk/reliability criteria will have cost implications and thus affordability consequences on wider NZTA programmers.

- **Leadership of standards and practices.**
  NZTA is the recognized leader and expert for pavements in NZ. To deliver effective leadership functions is critical and NZTA should invest, organize and operate, in collaboration with Industry, to prove best effect to its leadership function.

- **Industry Collaboration**
  Lessons learnt from early pavement failures, together with the "technical concerns" require a project to review, develop and communicate for correction and leadership guidance.
  The Reviewers suggest NZTA works collaboratively with the National Pavement Technical Group (representing industry) to plan a project to address these technical concerns, as a priority.

Appendix 1: Terms of Reference for Review

Review of the State Highway Pavement Delivery System

Terms of Reference

Purpose

To review the current NZ Transport Agency end to end system delivery requirements for new pavement and rehabilitation construction and to assess these requirements in terms of best value for money to deliver on New Zealand's land transport objectives. The NZ Transport Agency's value for money investment principle is "the delivery of the right outcomes, at the right time, at the right cost and financed at the right level of risk"[1].

Background

Following concerns over a number of pavement performance issues in state highway pavement construction projects, and with an opportunity to improve the value for money from our capital investments, an industry group with representation from ACENZ, CCNZ and the NZ Transport Agency was formed to assist in identifying the issues and developing improvements to our approach. With a focus on improving pavement quality, these changes were largely focused around design guidelines and responsibilities, tender documentation and quality management on site.

Over the past two years, these improvements have been and are being phased into our capital projects and pavement renewal programmes. Some projects are now in construction and network contracts are yet to be renewed therefore many benefits are still to be quantified.

This review will take a step back and see if there is anything more we could or should be doing to improve our (collective) performance. While the review is not expected to generate a fundamental change to systems and processes, there may still be opportunities to clarify and supplement existing pavement specifications, design processes and construction delivery.

Scope

The review should take a collaborative and beneficial approach that includes the following stages:

- Carry out interviews with a wide cross-section of industry representatives that includes consultants, contractors, industry bodies and NZ Transport Agency staff, to gather background views.
- Establish and document the key process's and steps in our current pavement delivery system, with the assistance of system owners and industry representatives.

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[1] NZTA Planning & Investment Knowledge Base at https://www.pikb.co.nz/home/the-way-we-work/nz-transport-agency-planning-and-investment-principles/affordable-and-achieves-value-for-money/

- Review these systems and processes against international best practice to determine what critical gaps exist in terms of achieving best value for money.
- Analyse the findings of the review, against the CCNZ position paper and against the NZ Transport Agency's procurement and delivery approach, to determine if further changes to current practice are required.
- Provide recommendations and report back to the NZ Transport Agency and industry.

Deliverables and Timeframes

Report with recommendations to be delivered within three months of engagement.

Independent Reviewer/Author

Requirements of the reviewer/author;

- Independent and unbiased
- Has prior knowledge of NZ pavement delivery systems
- Undertake the review to recognised standards

Noted Exceptions /Outside scope of Review

The review should be completed independently and in parallel to project work at the NZTA i.e. the review should not interfere with progress on any NLTP funded projects including research and development activities and contract tendering or negotiations.

Appendix 2: Previous Pavement Review.

Summary of the Report by Chris Olsen Contracting (November 2015)

"Collecting Information on the Pavement Quality on Construction Projects".

Last year (2015) the New Zealand Transport Agency commissioned Chris Olsen Consulting to report on pavement quality on its state highway network projects.

The findings were delivered in a 26 page document called 'Collecting Information on the Pavement Quality Of Construction Projects', and presented to the Transport Agency in November 2015.

It was thought that the report might have been discussed at the Transport Agency/NZIHT roading conference at Waitangi late last year. However, the agency needed to consider the recommendations under its "Quality Right, No defects" project , so we are now able to provide our readers with some of the report's highlights and we thank both the Transport Agency and Chris Olsen for this opportunity.

"The Transport Agency should be commended for commissioning this report to look at how it can further improve the construction quality of its large projects," says Chris Olsen.

Driving the commission was a concern that pavement quality was "not adequate in all cases". The Transport Agency wanted to know why pavement quality was variable around some projects and "identify possible improvements in the pavement quality of construction projects".

People within the Transport Agency, consultants (the agency's principal advisors) and 19 contracting 'practitioners' across four case studies were interviewed. All consultants and contractors involved had won large state roading contracts through a tender selection process (including non-price attributes), and have substantial work experience on a large construction project. Using an interview process and 58 questions, a 'panel of experts' solicited around 1100 responses and views on pavement quality from these participants. Both the questionnaire and a resulting draft report were reviewed and verified by the NZTA, ACENZ and CCNZ.

The Transport Agency gave an assurance that all the information collected during the research would only been used for 'continuous improvement' and not for the resolution of any contractual issues.

"This was important for ensuring that the real issues were highlighted and it's great to see that this has resulted in positive changes in the way the Transport Agency deals with contracts," says Chris. This was evident when the 'Huntly' Design and Contract (build) contract was announced last year with its prescriptive approach to pavement quality.

Key Findings

1. The average rating over all contracts concerned (with the smallest being a $30 million project and the oldest 10 years) for achieving the required pavement quality rated at 4.9 out of 10.
2. The general performance of the Design and Construct (D&C) contract sample projects proved a "serious concern".
3. The one Alliance contract case study produced better pavements, even though it had only one KPI. This was because of its inherent "best for project" KRA which meant all parties ensured any problems with the Principal's Requirements and KPIs were resolved.

4. While parties involved with the D&C contracts rated their performance of achieving the project's Principal Requirements as an average of 8 out of 10 and rated the achievement of their definition of quality at an average of 5.9 out of 10 – the quality of the finished product was somewhat lower. In comparison, the Alliance contract scored between 8 and 9.5 out of 10 on all three ratings.
5. "The D&C contracts struggled to produce quality pavements because the combination of less than optimum KPIs and a competitive market consistently produced thin, high risk, low cost pavements that sometimes appeared to compromise future lowest whole-of-life maintenance costs, coupled with a reluctance of project teams to make changes," notes the report.
6. Contract management and relationships scored highly across the contract parties with the exception of one project where the relationship between the project team and the Transport Agency's pavement team had a 'difference of opinion'.
7. "In hindsight, to avoid such situations arising again, the Transport Agency's pavement experts should be brought into the project team to help it address the issues and clear protocols developed for improved communication between the Pavement Team and the contract parties," the report recommended.
8. While parties were generally aligned at the start of a contract in terms of quality management systems they; "nearly always became miss-aligned during the project because of the contractor and the Transport Agency's Pavement team having different interpretations of KPIs."
9. The report recognised the differences and benefits between the two contract styles, such as continual improvement through an Alliance project and the opportunity of pushing innovation in a D&C contract, although it found in its sample case studies little innovation and mostly cost cutting. Overall, innovation was rated at only 5.9 out of 10. Contractors were rated at 7.6 out of 10 for making submissions to support innovative proposals, but all parties rated the agency's processes for approving changes to enhance innovation at only 3.6 out of 10.
10. The report also found issues with the contracting sector. There was a direct correlation between poor pavement construction quality and no third party MSQA review of the contractor's quality management systems.

Report Recommendations

The report advised the Transport Agency to adopt a number of processes for improving pavement quality in construction projects.

They included:

a. Setting adequate Principal Requirements commensurate with an appropriate contract model. For D&C contracts this could mean further developing the KPIs, specifying minimum requirements or requiring long-term performance warrantees.
b. To consider Net Present Value for whole-of-life pavement maintenance costs when awarding tenders.
c. Make an effort to improve alignment between the agency and contractor around on-going design expectations and the design Quality Management System.
d. Provide clear contractual requirements, incentives and penalties around expected pavement life.
e. Make sure design criteria and assumptions are verified during construction by the client and changed if necessary.
f. Develop clear contractual communications protocols and expected communication behavior for Project Teams and the Transport Agency's Pavements Team when interacting with contractual parties.

g. Make sure specified pavement life expectations and funding objectives are clearly and transparently aligned before awarding tenders.

h. Verify the onsite application of the contractor's Quality Management System through a clarification of the MSQA consultant's role.

i. Develop a Quality Management System like RAMM that collects "as laid" data (because utilities have had difficulty in accessing this information).

j. Develop a quality system that covers Pre-tender, Tender, Pre-award, Design Development, Construction, Post-Construction, and "as laid" records, to ensure consistency across the agency's staff and regions.

k. Develop a process for improving the understanding of modified pavements, and sharing the lessons from this, especially with the agency's project managers and MSQA consultants, because modified pavement performance is critical in meeting the KPIs, but is generally unchartered water with many professionals having different views.

l. Develop a process for making "best for project" pavement type decisions because of the many different individual professional views.

m. Have detailed quality plans available for the client prior to the start of construction and develops an audit process in collaboration with the contractor and consultant. "This will include third party sampling and testing and review of all quality records and on-going work to ensure it is completed in line with the quality plans any design assumptions."

Comments from the participants

An interesting part of the report is a summary of responses made in the 'any other comments' sections of the questionnaire. They included:

i. "Design theory and construction don't always match.

ii. "Nowhere in Austroads standards are there deflection subgrade strain requirements, so is unconventional to use them because they are largely unproven. (Yet the basis of our design is subgrade strain).

iii. "Sometimes instead of solving design problems, designers take the easy way and simply raise the bar.

iv. "Systemic failure in using granular pavements with chip seals on major roads, as the pavements can't handle the ESA (rutting) and the high traffic volumes reduce the amount of bitumen making the chip seal unwater- proof.

v. "Traffic volumes are now in excess of those that a granular pavement can handle – why use granular pavements for D&C?"

vi. "And this wee gem: "At the end of the day you get what you pay for."