NACOE

NATIONAL ASSET CENTRE OF EXCELLENCE

Highlights Report 2014 – 15

AN INITIATIVE BY:

Queensland Government

arrb GROUP

To contribute to lower-cost, quality infrastructure through knowledge and research

arrb GROUP

Queensland Government

Our Mission

The purpose of the Queensland Department of Transport and Main Roads (TMR) and ARRB Group Agreement is to achieve engineering excellence across both organisations by improving the specialist capability and capacity of TMR and ARRB Group through a sustained, collaborative program of challenging projects which deliver superior technology and road transport solutions for the people of Queensland.

Strategic Objectives

COST SAVINGS

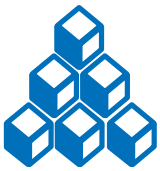
Delivering economic benefits to the Queensland network through cost-effective and higher performing pavements, refined asset management practices, efficient management of structures and by optimising road safety and network operation outcomes.

COLLABORATION

Working in partnership with industry, universities and government bodies to leverage research and resources, helping to deliver mutually beneficial outcomes.

DEVELOPMENT

Developing the capabilities of staff and disseminating learnings to regions.



IMPLEMENTATION

Facilitating trials, establishing research tools and infrastructure to help implement new technologies and practices in Queensland.

Foreword

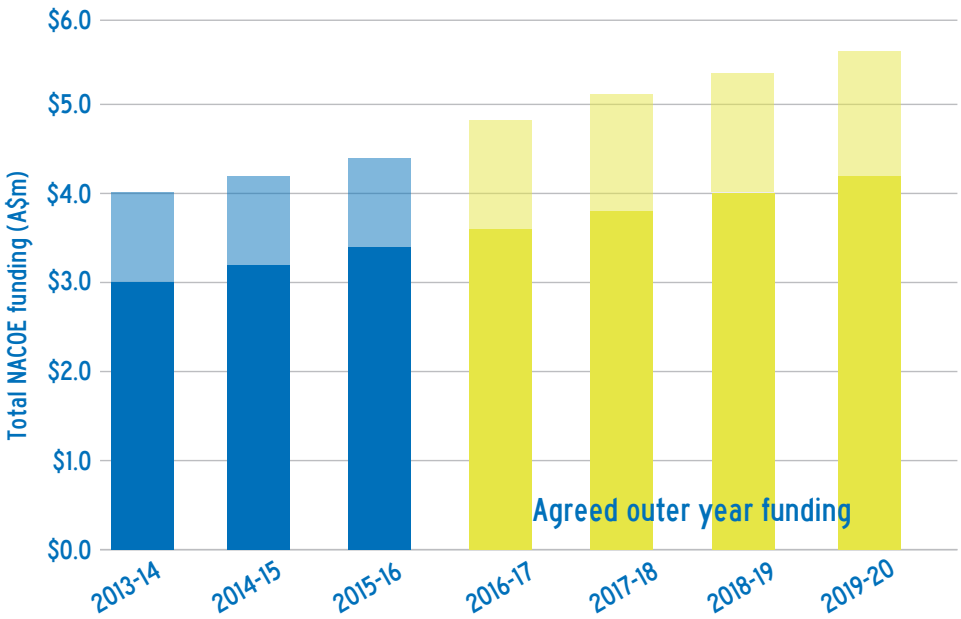
Queensland Department of Transport and Main Roads/ ARRB Group Agreement

In December 2012, the Queensland Department of Transport and Main Roads and ARRB Group signed a new partnership Agreement. The new Agreement has a broad scope and includes committed funding for capability development, research and technology transfer. The primary technical focus of the Agreement is to create a National Asset Centre of Excellence in Queensland. This centre will focus primarily on the pavements, structures and asset management disciplines, with the aim to raise technical capability and save TMR costs through improved decision making based on knowledge. The partnership Agreement was reconfirmed in December 2014.

Achievements across the first two years of the program demonstrate that TMR can, with confidence, achieve benefits far in excess of the costs.

The Agreement covers a rolling four-year program, and is renewed every two years. In 2013-14, the Agreement totalled $3 million with this figure rising to $3.2 million in the second year. The renewed Agreement commits funding of $3.4 million in 2015-16 rising to $4.2 million in 2019-20.

The Agreement also provides for funding of $1 million per year, increasing by $100,000 per year for TMR staff to work collaboratively with ARRB on the research program.



The Agreement aims to continue and enhance existing ARRB services in the following areas:

- establishing the National Asset Centre of Excellence (NACOE)
- provision of technology services
- co-location of ARRB and TMR technical staff
- establishing critical research tools and infrastructure needed to realise the benefits of NACOE
- full implementation of the Transport Infrastructure Product Evaluation Scheme (TIPES)
- capability development
- enhancing the relationship with Austroads
- a National Interest Services Memorandum of Understanding.
- a TMR/ARRB secondment Memorandum of Understanding.

This report focuses on key findings from the 2014-15 NACOE program of work. It includes interim findings from a number of projects which are continuing into 2016.

The program covers four key discipline areas:

- pavements
- asset management
- structures
- other, comprising:
  - network operations
  - road safety
  - heavy vehicle management.

TMR and ARRB are proud of the achievements to date under the Agreement and look forward to its expansion to be more collaborative with industry to further unlock innovation opportunities in the transport and roads sector.

ARRB Group Managing Director, Gerard Waldron and TMR Director-General, Neil Scales at the Agreement signing in 2014

Key Performance Indicators

The NACOE Board has outlined a series of key performance indicators by which to measure the outcomes of the Agreement. Some of the outcomes are highlighted here.

Benefit/cost ratios have been developed for a number of high-profile projects with direct economic benefits. The ratio indicated requires an assumed level of implementation of project outcomes, and includes all direct project costs. A more comprehensive benefit/cost analysis is being developed for coming years, which will assist in directing funds to areas of high priority.

31
Projects completed

6:1
Benefit/cost ratio

93%
Milestones delivered

16
Publications developed
including Technical Notes and Specifications

5%
Funding from external partners

85%
Funding to priority research areas

Note: All numbers are rounded.

Client Feedback

The 2014-15 client feedback survey found a strong level of support for the program within the group of TMR Project Managers.

Respondents believe there are benefits to be realised by TMR and would support continuation of the program provided research is specifically targeted to the right areas.

Contributing factors to project success include managing projects locally out of the ARRB Brisbane office, and where project proposals are jointly developed by both TMR and ARRB.

In the future, the program would benefit from more frequent presentation of interim findings, and to ensure that project scope is very well defined before start-up.

94%
Satisfied or very satisfied with overall management of projects

80%
Satisfied or very satisfied with quality of final outputs

Directions for 2016 and Beyond

The first two years of the program had a focus on achieving 'quick wins', by directing research funding to areas with strong prospects of cost savings.

As the NACOE program matures and early research objectives are completed, there will need to be an increased focus on several aspects, including:

- seeking joint funding from external partners, including industry and universities
- more workshops and knowledge dissemination, particularly through TMR regions
- increased capacity building and development of research talent, through retention of expert personnel, further education, secondment opportunities and student internships.

There is still a desire for co-location of TMR and ARRB technical staff and progress has been made towards a business case for accelerated pavement testing (APT) in Queensland.

100%
Believe projects delivered value for money

50%
Can identify potential savings to TMR from projects

85%
Believe projects will lead to increased knowledge or capability for TMR

Pavements

The pavements program represents the largest proportion of the NACOE program, with roughly half the total projects and half the total investment. This program comprises a number of sub-programs, including asphalt, unbound granular and marginal materials, stabilised/modified pavements, surfacing and a number of technology projects.

The pavements program has the potential to deliver very significant cost savings compared to current practices, allowing for more road projects to be constructed. The major findings to date include:

- reducing the required depth for new full-depth asphalt pavements through the use of new mix designs (including the French high modulus asphalt - EME2) and through the refinement of overly conservative design calculations
- encouraging performance-based testing of asphalt designs through the use of tools such as the Hamburg Wheel Tracking Device and improving the long term performance of pavements and surfacings by reviewing specifications and adopting world's best practice in Queensland
- advocating the wider use of non-standard and/or marginal granular materials through performance validation and evaluation guidelines.

Moving into 2016 and beyond, the pavements program has a stronger focus on building upon these findings with field trials and collaboration with industry and universities so that the full benefits of these important research projects can be realised across Queensland.

Initiatives to reduce the required depth of asphalt pavements in Queensland

Implementing EME2, the French high modulus asphalt

Enrobés à Module Elevé Class 2 (EME2) technology was developed in France in the early 1990s. This technology is used extensively in Europe on heavily trafficked roads and airports with outstanding success.

Compared to conventional asphalt bases with unmodified binders, EME2 is characterised by a high stiffness, high durability, superior resistance to permanent deformation and excellent fatigue resistance. Internationally, asphalt base layer thickness reductions in the order of 20-30% have be achieved using EME2, when compared to conventional asphalt.

Over the past two years, TMR and ARRB have been involved in an effort to transfer EME2 asphalt technology to Australia. This project, *Cost-effective Design of Thick Asphalt Pavements: High Modulus Asphalt Implementation*, is aimed at developing guidelines for the structural design of pavements containing EME2.

In order to evaluate the pavement design concepts and in situ performance of EME2, the first trial in Australia was carried out at Eagle Farm. TMR, Brisbane City Council, the Australian Asphalt Pavement Association and industry partners collaborated on the trial.

Despite the EME2 base layer being constructed with 30% thinner asphalt than the control section of conventional asphalt, its measured structural capacity was similar. ARRB carried out the pavement design and the site set-up and also performed the in situ performance monitoring. Based on the success of this trial, TMR is now actively planning more use of this innovative asphalt throughout Queensland.

The new TMR Technical Note allows for a reduction of at least 20% in asphalt base layer thickness for EME2.

- French EME2 asphalt trialled in Australia for first time
- Superior properties to conventional asphalt mixes with improved performance
- TMR Technical Note published, allowing for asphalt base layer thickness reduction of at least 20%
- Contributing to savings of $15-18 million per year across the network

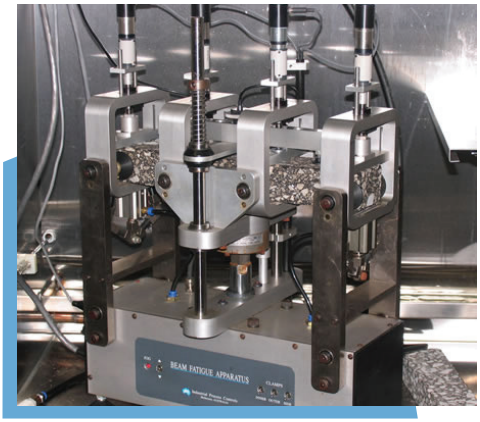
Long-life pavement alternatives for Queensland

Perpetual pavements are designed and constructed to ensure that they only require resurfacing, and never require full replacement. The challenge for this research is to find the minimum thickness of these pavements so that they remain perpetual.

TMR is working with the Australian Asphalt Pavement Association on this important research, which is complementary to the research into the effect of elevated temperature on fatigue.

- Perpetual pavements only require resurfacing, not full replacement
- Project is helping define the minimum thickness for perpetual pavements
- Potential to save millions of dollars on 'over-engineered' asphalt pavements

Pavements



Characterisation of asphalt fatigue at Queensland pavement temperatures

The current Austroads pavement design predicts a shorter fatigue life for pavements in warm climates compared to those in colder climates. This leads to thicker pavements in Queensland.

The objective of this continuing project is to review this assumption by characterising the laboratory fatigue performance of typical Queensland asphalt mixes at elevated temperatures. The findings of the study indicate that the fatigue performance of asphalt mixes can be successfully characterised using a new Austroads T274 protocol up to temperatures of at least 30 °C, although for some mixes there will be clear benefits in developing mix-specific fatigue curves.

The study lists a number of options for interim improvements to the asphalt pavement design methods used by TMR, including the optimisation of mixes in terms of balancing rut resistance, stiffness and fatigue performance, and encouragement of the use of innovative asphalt mix designs (e.g. EME2).

- Laboratory testing has demonstrated improvements to the characterisation of asphalt performance at typical Queensland pavement temperatures
- Interim improvements may leads to thickness reductions in the order of 50 mm, which equates to $15 million in savings per year.

These measures will deliver a significant reduction in pavement thicknesses – initially of 50–60 mm, but increasing with further validation. This equates to a cost saving of about $100,000 per lane-km. This change will significantly reduce the number of pavement runs and hence construction time.

As a result of the three NACOE asphalt research projects, TMR has already reduced the required asphalt thickness for projects in Queensland by around 50 mm in its recently released Pavement Design Supplement, with further reductions likely. Since 2005, TMR has constructed an average of 150 lane-km of new construction with full-depth asphalt each year. The thickness reductions that can be achieved by adopting these technologies and practices across all new full-depth asphalt projects equates to a $15-18 million saving for TMR each year. Early conclusions of this research are believed to be conservative, with further savings likely to be validated and rolled out in subsequent years with additional research and ongoing field evaluation.

Maximising the use of rubber from end-of-life tyres in road construction in Queensland

Application of ground tyre rubber in asphalt and seals provides a high value application of recycled material. Overseas experience, particularly in the United States, where recycled rubber is widely used, shows that the use of crumb rubber modified (CRM) binder in both open graded asphalt and sprayed seals can lead to much improved field performance. Conventional open graded asphalt provides significant road noise reduction, and improved safety, but requires regular replacement by milling out and repaving with new asphalt. CRM open graded asphalt provides increased service life, while maintaining the functional performance and economic benefits.

Additionally, there are significant environmental benefits in reduced CO_2 emissions, and reduction in the use of non-renewable road construction materials. The project has received strong support from the Queensland Department of Environment and Heritage Protection due to the increasing need to find a use for discarded tyres.

If CRM binder was used widely in asphalt and sprayed seals in Queensland, a significant proportion of end-of-life tyres could be put to beneficial use, providing a cost-effective alternative to conventional binders. This could potentially save the industry 10% or more in binder costs. TMR spends over $40 million per year in spray seal binder costs. Shifting half of new works to CRM binder would save in excess of $2 million in binder costs alone.

A trial of crumbed rubber seals was conducted in March 2015, and a further trial of crumbed rubber binder in asphalt is planned for 2016.

During the next phase of the research, NACOE proposes to work with industry to develop a new specification for CRM open graded asphalt. This is urgently needed in Queensland to replace conventional open graded asphalt with a longer-life solution.

- Tyre rubber can be utilised in asphalt pavements and seals
- Environmental benefit as well as improved field performance
- First trial of crumbed rubber seals in August 2015, trial of crumbed rubber asphalt is upcoming
- Savings of 10% or more in material costs could save $2 million per year across the state
- Working with industry to develop specifications

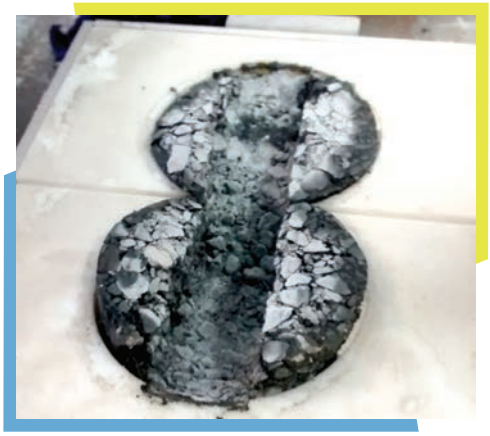
Review TMR's specifications to deliver desired surfacing performance

The TMR guidelines for selection of initial surfacing properties require review against best practice to ensure TMR continues to meet its duty of care and to seek opportunities to continue to reduce maintenance costs. The major performance requirement for surfacing continues to be skid resistance, as it is closely linked to crash frequency and safety costs.

The project has developed improved guidelines and specifications for the selection of surfacing materials based on the polished aggregate friction value (PAFV). These new guidelines will allow for a better prediction of field performance, reduce whole-of-life costs and better manage high risk crash locations.

NACOE
NATIONAL ASSET CENTRE OF EXCELLENCE

Pavements



- TMR commissioned first Hamburg Wheel Tracking Device in Australia
- Device has proven to be capable of identifying moisture sensitive asphalt mixes before performance issues arise in the field
- Device is available for use as a performance-based research and mix design tool

Commissioning the Hamburg Wheel Tracking Device

As a part of the move to performance-based asphalt specifications, TMR commissioned the Hamburg Wheel Tracking Device (HWTD), a laboratory testing device designed to measure the susceptibility to moisture-induced damage and rutting resistance in asphalt mixes. Moisture-induced damage and stripping have been identified as a risk with asphalt pavements in Queensland and the HWTD may assist in identifying moisture-susceptible mixes before performance issues arise in the field. TMR has the only HWTD in Australia.

Laboratory testing proved that the HWTD is capable of identifying the combined impact of moisture sensitivity and the stability of various asphalt mixes. The boundaries of the equipment capabilities were established. The device is capable of testing both asphalt slabs and cylindrical specimens (either field cores or laboratory-prepared samples). Testing can take place at a range of temperatures and air voids to match the materials and project requirements.

Discussions with industry leaders have helped to illustrate the role that the device can play within the framework of the current materials testing program, and a preliminary test method has been produced to facilitate consistent and comparable results. It is envisaged that the HWTD will prove to be a valuable tool for identifying moisture-sensitive asphalt mixes and this will reduce the risk of premature failure due to stripping.

The device is now available for use in research and as a mix design resource.

Initial seals in Queensland

Queensland has been experiencing problems with primerseals used on previously unsealed roads ('initial seals'). This project sought to collate the current state of knowledge on initial seals, document good practice and identify risk factors. Two workshops were conducted with industry and TMR personnel, identifying key issues including binder grades, treatment planning and scheduling, design approach, and aggregate embedment.

A Queensland specific 'Work Tip' has been developed which provides interim guidance until TMR and Austroads documentation can be updated. TMR is also actively addressing some capability gaps that have been identified in knowledge of seal technology, due to loss of experienced practitioners through retirement.

Introduction of the 'Modified C' grading to MRTS05

The TMR Technical Specification Part 5 outlines a series of grading envelopes which can be specified by TMR under the project requirements. Some regions have been experiencing problems with 'boney' granular pavements specified to conform to the C grading. This has led to the introduction of a Modified C grading, which effectively removes the outer limits of the C grading. The major change is an increase in very fine material, which is intended to reduce permeability, improve workability on site and lead to a better surface finish. Anecdotal evidence from regions using the modified grading curve suggested that some benefits have been realised, however no comprehensive studies had been undertaken prior to this project.

A series of site inspections, consultation with select regions and industry, and a comprehensive laboratory testing program established that the Modified C grading does reduce permeability and has only a minor effect on strength. Evidence suggests that moving to the grading may lead to cost increases, for some quarries, depending on their source rock. However, the research has validated that having a less permeable grading will significantly improve the performance of pavements across regional Queensland. One of the major contributors to the 2010-14 $6.4 billion flood recovery program was damage to permeable pavements. Moving to a more resilient pavement design could conceivably prevent $1-2 billion of damage should a similar series of events occur in the future. Given that TMR spends almost $100 million on unbound granular base each year, a saving of only 15% in whole-of-life cost as a result of the change to Modified C grading could save $15 million per year once this change is fully rolled out, and this is believed to be conservative.

The shift to a Modified C grading appears to reduce the likelihood of water infiltration, as well as to provide improved workability, constructibility and surface finish. Changes have been implemented in the latest update to the MRTS05, incorporating a Modified C grading in addition to the existing C grading, allowing this grading to be specified for TMR granular pavement works. TMR has agreed with Cement, Concrete and Aggregates Australia (CCAA) to progressively adopt the new grading, as quarries 'tool up' to supply the improved base material.

- The Modified C grading may be specified for some granular pavements to reduce the risk of moisture damage
- New grading has been incorporated into the MRTS05 specification and is being progressively adopted by industry

Pavements

Evaluating the performance of TNRP flood repair works

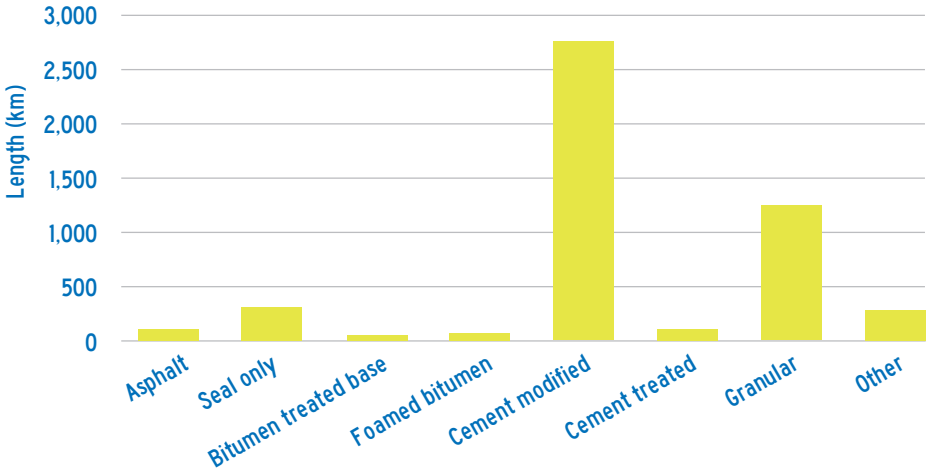
This is a three-year project to identify best practices and lessons learnt from the Transport Network Reconstruction Program (TNRP), specifically in the application of pavement technology through a number of treatment options employed.

Year 1 was focused on gathering and compiling the relevant program information at a one-day workshop with Regional Program Offices (RPOs), site visits, and interpretation of the TMR ARMIS database. The short-term outcome was to identify through analysis of the vast amount of information collected, specific jobs to be studied in Years 2 and 3 of the project.

The findings from the project will contribute to the improvement of the design guideline for future flood recovery works. Given the scale of the area affected, variations in pavement works undertaken and the construction practices adopted in each region, the TNRP provides TMR an opportunity to identify optimal reconstruction practices. TNRP pavement-related repairs to approximately 4,900 km of road have an estimated cost of $3.5 billion of the $6.4 billion overall program. Even a small (5%) improvement in practices (for example, Modified C grading) and design guidelines would translate to $175 million in savings for TMR in a similar future program. Also, a further saving in ongoing maintenance costs can be achieved by adopting better pavements based on NACOE research. With projected maintenance expenditure in excess of $2 billion over the next ten years, a saving of 10% in maintenance spend through improved pavement performance could deliver savings of $20 million per year.

- The TNRP flood recovery program included around $3.5 billion of pavement works, covering 4,900 km
- Project has identified key areas for improvements in design guidelines and practices, with a small improvement in efficiency of 5% worth $175 million in a future flood recovery program

Length of treatments under TNRP



High strength granular bases: TrackStar Alliance project

The Centenary Highway upgrade between Springfield Parkway and the Logan Motorway interchange was originally designed to be constructed from full depth asphalt. To reduce costs, and allow increased project scope on this greenfield site, the project was redesigned to be constructed from unbound high strength granular (HSG) base. Traditionally, this option would not have been considered, due to its perceived high risk, however in this instance, on a greenfield site, with several locally available quarries that can produce the required HSG base, the risk was accepted by TMR senior management.

- High strength granular bases are an alternative base layer to reduce costs
- Trial has been successfully conducted at the Trackstar project on the Centenary Highway
- TMT Technical Note and guidance have been provided for future works

The TMR/ARRB project team worked with the contractor in an effective partnering arrangement, to focus on the risks and mitigate them, by applying sound quality control processes to manage the construction materials, and by working closely with the TMR laboratory to develop criteria for acceptance of moisture levels in pavements before they were sealed. TMR has experienced several serious premature failures due to saturated bases in the past, and is well aware of the challenges with this material. The team was particularly fortunate to experience dry weather during construction, and this assisted greatly with moisture control. As well, the quarry which supplied the base has uniform and sound source rock, and highly developed processing equipment to ensure consistent base quality.

Based on the findings of the study, TMR has developed a Technical Note and Technical Specification Annexure for the utilisation of HSG base for heavy-duty unbound granular pavements.

TMR and ARRB will continue to monitor this project. While conventional granular pavements will continue to be used in the lower trafficked roads throughout Queensland, where the risks are lower and can be managed, widespread application of HSG on the more highly trafficked network is likely to be constrained by availability of suitable and consistent base material, availability of greenfield sites, and acceptance by decision makers.

This project has demonstrated that HSG base can (under controlled conditions) provide a viable solution for some heavily trafficked roads. Initial structural assessments indicate that a very long service life can be expected.

NACOE
NATIONAL ASSET CENTRE OF EXCELLENCE

Pavements

Investigating stabilisation practices in Queensland

This projects aims to develop a systematic approach for selecting the most appropriate stabilisation technology for a given application considering traffic, climate, environment, parent material and budget constraints, in addition to documenting best practices for mixture proportioning, structural design and construction of stabilised pavement layers.

- Most plant-mix cement modified base (CMB) and in situ foamed bitumen stabilised pavements in good to excellent condition and exceeding design life
- Technical Notes published on treatment selection methodology and best practice guidelines
- Increased use may lead to savings of $50-130 per m^2, or around $5.4 million per year

Most plant-mix cement modified base (CMB) and in situ foam bitumen stabilised (I-FBS) base were the focus of the 2013-15 program. However, all of the pavement stabilisation technologies commonly utilised in Queensland will be examined in future research efforts.

The majority of the PM-CMB and I-FBS pavements along the state-controlled road network are in good to excellent condition, including several that have exceeded the original service life estimates. Testing of a small proportion (approx. 10%) of the network indicated that many pavements have significant (> 106 ESA) structural capacity remaining.

Queensland practices for mixture proportioning and construction generally align with international best practice. However, significant discrepancies were identified in the structural design of both PM-CMB and I-FBS pavements. Fundamental differences in practice stem from the controlling failure mode and underlying design assumptions.

Technical Notes have been drafted in collaboration with TMR outlining a standard technology selection methodology and highlighting best practices for the utilisation of PM-CMB and I-FBS.

Stabilisation technologies provide increased resilience for flexible pavements in high-exposure (traffic, environment and/or climate) situations, as compared to unbound granular materials, at a fraction of the cost of full-depth asphalt, 25% and 60% for PM-CMB and I-FBS, respectively.

Increased utilisation of these technologies, in accordance with best practice, can result in significant reductions in both construction and maintenance expenditure. An economic analysis has shown that utilising a cement modified base can lead to savings of $50-$130 per m^2 when compared to a similar standard hot-mix asphalt base layer, which translates to savings of up to $1 million per kilometre treated. Replacing just 10% of new full-depth asphalt pavements with high performance stabilised granular pavements would result in $5.4 million in savings per year.

Review of the wet/dry strength variation testing limits

Around 70% of the Queensland state-controlled road network is composed of unbound granular layers with a thin bituminous surfacing. In-service deterioration (lack of durability) is one of the leading causes of premature failure for these pavement types. Resistance to mechanical degradation is determined in Queensland by measuring the wet/dry strength variation. However, it has been proposed that the current specification limits may be too restrictive. The objective of the project was to evaluate the appropriateness of the wet/dry strength variation test and the current technical specification limits for identifying coarse aggregates that may be susceptible to in-service deterioration.

The specification limits in Queensland were found to be the most stringent in Australia, but equivalent to some international requirements, such as in South Africa. Limitations of wet/dry strength variation include low repeatability and reproducibility, as well as poor replication of in-service loading conditions.

A suite of alternative durability assessment methods was examined using basaltic unbound pavement materials representative of the range of products currently available in Queensland. Based on the limited testing carried out as part of this investigation, micro-Deval abrasion was observed to provide better simulation of in-service loading conditions, assessment of both fine and coarse aggregates, increased repeatability and reproducibility and significantly improved laboratory efficiency. Further testing is required on the range of mineralogy and quality standard of aggregate products currently available in Queensland to refine the testing methods (TMR Q229A/B) and establish reliable criteria limits.

Development of a performance-based evaluation protocol for non-standard and marginal granular materials

The satisfactory long-term performance of unbound granular materials is achieved by ensuring the selected materials conform to standard specifications that have been validated by historical performance. High-quality compliant aggregates are not readily available in large sections of Queensland. Locally available materials are commonly rejected due to non-conformance, but may provide satisfactory performance in select applications (fit-for-purpose). The objective of this project is to investigate the feasibility of a standard methodology for evaluation and selection of non-standard and/or marginal base and subbase materials.

It is anticipated that the developed decision support tool will increase the utilisation of locally available materials, reducing infrastructure cost, environmental impact and operational risk while encouraging innovation. Preliminary evaluation protocols have been developed using both standard and non-standard assessment methods.

- Many regions of Queensland use non-standard and marginal materials
- Performance-based evaluation tools will increase the availability of local materials without sacrificing performance
- Preliminary evaluation protocols now available

NACOE
NATIONAL ASSET CENTRE OF EXCELLENCE

Pavements

Utilising bagasse ash and fibres in pavement construction in Queensland

Queensland is one of the largest sugarcane producing regions in the world. The process of producing sugar results in large quantities of a fibrous by-product known as bagasse, which is often incinerated to generate energy for the sugarcane processing plant or fed back to the power grid. The residual by-product, bagasse ash, is currently considered a waste material requiring storage in stockpiles or disposal in landfills.

- Large volume of bagasse ash as waste product from sugarcane industry
- Can potentially replace one-third or more of lime used in reactive subgrades
- Further testing and industry collaboration required to determine potential cost savings

Bagasse ash and fibres have been used in pavement construction in other sugar-producing countries, most commonly by blending bagasse into expansive subgrade soils, taking advantage of the pozzolanic effect of the ash in a similar way to fly ash and blast-furnace slag. The vast quantities of excess bagasse ash and fibre produced and stored along the Queensland coast present opportunities for an alternative treatment option for expansive subgrades while providing both environmental and economic benefits.

The initial laboratory testing phase, conducted with industry and university partners, has shown promising results for treating expansive soils with a bagasse ash/lime blend, in terms of reduced linear shrinkage and improved strength. The second year of the project will look to explore the use of bagasse products in Queensland through further laboratory testing and a field trial.

Long-term pavement performance (LTPP) program

A key requirement for a robust pavement engineering research program is that findings can be supported by and validated against long-term field performance data. The LTPP program provides the crucial field data to narrow the gap between the design model prediction and the real-world outcome. This is particularly true for new pavement technology developed by the NACOE projects.

Typical pavement design lives can be 40 years or more, which means that monitoring a pavement in the initial few years is inadequate to predict failure many years later. There are currently only seven LTPP sites in Queensland, which is clearly not adequate to cover the large number of project permutations throughout the state.

In the absence of accelerated pavement testing, this project allows for a strategy to gather real-life pavement performance data to support NACOE projects in a cost-effective, coordinated and sustainable manner. By maintaining this database, the benefits from the NACOE program can be realised decades into the future.

Benefits of traffic speed deflectometer (TSD) data in pavement analysis

The TSD is a truck fitted with Doppler lasers and a range of sensors that can measure the response of a pavement to loading at highway speeds. The deflection profiles can then be used to derive the bearing capacity and fatigue life of the pavement at small intervals. This allows for rapid data collection across the network, with roughly 10,000 km of the Queensland network now surveyed each year between April and June.

This is a major improvement over existing methods, including the falling weight deflectometer (FWD), however the data requires a relative comparison between pavement types and across other deflection measurements. The study has found a strong correlation between TSD data and FWD measurements for maximum deflection and overall deflection bowl shape .

Field validation of 3D noise modulated ground penetration radar

This project focuses on the appropriate moisture-permittivity relationships, adapting analysis methods developed on synthetic data to real NM-GPR data, and field and laboratory validation of the methods.

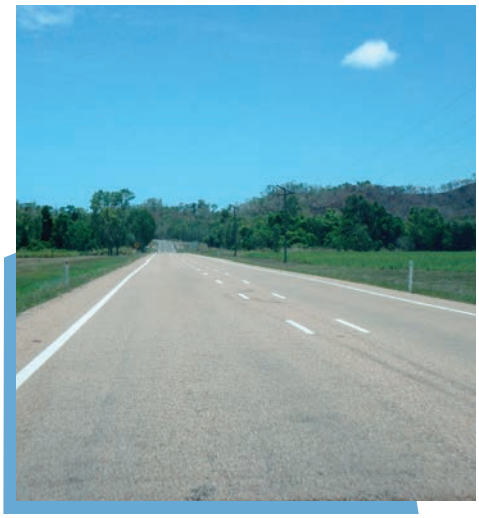
The first trial (in Australia) was successfully carried out at a truck stop on the Cunningham Highway at Fischer Park. This has shown that it is now possible to predict moisture from field measurements of NM-GPR. Further refinements to improve accuracy and reliability are in progress.

Instrumentation for real-time condition and performance monitoring of in-service pavements

In order to capture the benefits of innovative practices and the use of marginal materials, it is essential to monitor the ongoing performance and condition of pavements. A range of low-cost instrumentation technology is now available that allows for non-destructive measurement of pavement condition and performance in real-time with wireless monitoring , thus leading to better informed design, research and decision making across the network.

Many of these devices are already positioned across the network, delivering targeted real-time monitoring at high-risk locations. In addition, the project has identified a range of devices that may be included in future and continuing NACOE research projects, enhancing the outcomes of these projects.

Asset Management



The asset management program comprises four projects, and makes up around 10% of the overall NACOE investment.

The program has delivered several significant projects to date, with a focus on enhancing existing asset management models, as well as the development of new tools to incorporate into practices. This includes the development of new skid resistance management practices and pavement performance modelling for the pavement management system.

It is expected that the program will deliver the following benefits to TMR:

- more sophisticated and accurate asset management tools and models, which will enable TMR to better prioritise maintenance and rehabilitation spending
- adoption of world's best practice, in particular for skid resistance measurement and monitoring
- life cycle costing of asset management strategies, with a focus on how to improve resilience of the network to rain and flood events with a limited budget
- assisting TMR and regions with the implementation of road asset management contracts, which are growing in usage across Queensland.

Life-cycle costing implications and network performance risks of rain and flood events during 2010-13

During 2010-13, the Queensland road network was impacted by a series of major cyclone and rainfall events that caused several billion dollars damage to the network. The Transport Network Reconstruction Program (TNRP) was established to facilitate the state-wide recovery program.

This project seeks to quantify the impact of these events in a life-cycle costing framework, and to identify the funding levels required to improve the resilience of the network as it responds to future rain and flood events. A series of case studies was developed that enabled a comparison of three investment scenarios; the base case of what actually happened, a full resilience scenario and a 'stitch-in-time' approach to road rehabilitation.

A life-cycle costing model was developed to facilitate this analysis. Findings to date suggest that large benefits can be realised through the full resilience option, but that this comes at a very high agency investment, while the stitch-in-time approach (depending on the road and region) may allow lower total spending while also reducing the flood damage risk.

This project continues into a third year where network-wide conclusions will assist TMR in deciding on the most efficient allocation of funding to realise optimal economic and performance outcomes while achieving whole-of-life cost savings.

- Rain and flood events cause significant pavement damage
- Seven case studies have found that better targeting of maintenance and rehabilitation could improve network resilience
- Final year of project to look into network-wide implications of improved life-cycle costing modelling

Incorporating uncertainty in pavement management system (PMS) modelling

TMR is developing road asset management contracts for South-East Queensland, with a possible transition to outcome-performance-based contracts within the next five years. Underpinning these performance contracts will be a comprehensive asset management system that is currently being developed by ARRB that will benchmark predicted performance and optimise investment strategies.

The objective is to apply a probabilistic, quantitative risk-based approach to the modelling of pavement asset performance and ensure it utilises the full set of historical data and forecasts for key variables. This will help ascertain the degree of uncertainty of the forecast and allow TMR and its contractors to select a strategy which balances investment cost and risks.

The system framework has been developed and example analyses have been completed. It is anticipated that this system will lead to investment savings in the order of 10-15% through appropriately targeted treatments and improved asset management efficiency. The project continues into 2015-16 with the focus on completing the fully operational model.

Asset Management

Calibration of traffic speed deflectometer (TSD) data

This project facilitates analysis of TSD data through calibrating readings across the network. TMR has surveyed a large part of its sealed network using the TSD and is seeking an effective way to utilise the collected data. The aim of the project is to demonstrate how the collected TSD data can benefit TMR's existing asset management practices.

The project identified a suitable method for TMR to convert the TSD data to pavement strength indices which could be collected by conventional devices such as the FWD and deflectograph. Two case studies, demonstrated that the converted TSD data can be smoothly incorporated in both simple and complex asset management tasks to help make more accurate and reliable network management decisions.

Scanning and scoping technologies that evaluate the remaining service life of spray seals using advanced bitumen testing technologies

Large parts of TMR's road network are sealed with sprayed seal. Seals are sometimes required to last 30% longer than their design life, with uncertainty over the real risk of failure. This project is aimed at exploring the potential of measuring bitumen properties relevant to aging and performance during its service life with non-destructive methods, looking beyond the techniques currently used.

The study identified a number of issues related to current sprayed seal condition assessment methods. The study also revealed that there is huge potential in enhancing current practice in assessing remaining life of the sprayed seal network through examining bitumen's chemical components.

It was recommended that TMR cooperate with the transport industry, other road agencies and international partners who face similar issues to identify a prospective tool. It also recommended that a sampling and testing program is immediately adopted to allow TMR to assess and manage the risk of failure for its sprayed seal network.

This will allow enhanced network management practices, significantly reducing the risk of failure and enable asset managers to make rational decisions on reseal intervals.

Structures

The structures program comprises four projects representing around 20% of the NACOE investment in 2014-15.

Two of these projects have focused on measurement and analysis of the actual in-service performance of bridges in Queensland under vehicle loading. Additionally, two projects have reviewed the current procedures behind health monitoring and asset and risk management of bridges in Queensland.

The structures program will seek to deliver benefits to the network in a number of ways, including:

- improving bridge monitoring and management through the use of advanced systems and by adopting world's best practice in asset and risk management
- analysis of vehicle interactions on load-limited and critical bridges to gain a better understanding of the capacity and performance of these structures
- destructive testing of a decommissioned bridge to evaluate performance under ultimate loading
- development of staff capacity in the use of advanced assessment technologies and instrumentation of structures.

NACOE
NATIONAL ASSET CENTRE OF EXCELLENCE

Structures

- TMR invests heavily in load restricted bridges but would like greater clarity on dynamic loading of these structures
- Unique testing to date has shown that vehicle and suspension type influences overall structural response
- Better understanding means reduced risk and potential savings of $20 million on replacement and strengthening costs

Measurement of bridge-vehicle interaction under live load

TMR is responsible for approximately 3,000 bridges and 4,000 major culverts, with a gross replacement asset value in excess of $11 billion. Of this number, there are several bridges that are subject to load and permit restrictions, with costs to upgrade or maintain these structures in the order of $120 million.

Structural assessments conducted on these bridges take into account the dynamic amplification of load due to heavy vehicles by applying various codified factors from AS 5100. Of particular interest is the use of the Dynamic Load Allowance (DLA) factor, currently set at 0.4, regardless of vehicle, structure or component type. TMR is investigating whether the application of this factor in theoretical assessments can be reduced for substructure components. Such a reduction could lead to elimination of unnecessary replacement and/or strengthening costs, removal of access restrictions, and increased freight movements. Additionally, this research is unique as there has been little published or documented in relation to the area related to superstructure interaction.

To investigate this, TMR and ARRB embarked on an extensive bridge load test program on two representative pre-stressed concrete bridges. Both structures also have concrete I-girders, which represent approximately 60 bridges on the Queensland network with known deficiencies. The objective of the research is to develop improved understanding of bridge performance through measurement and comparison of the dynamic response of representative superstructure and substructure components. The results also enable analysis of the load distribution on the superstructure I-girders. The load testing was successfully completed in May 2015 on the Dawson River Bridge and Neerkol Creek Bridge on the Capricorn Highway. A range of heavy vehicles was used, travelling in different directions, at different transverse locations across the deck, and at different speeds.

Final results are pending; however, early indications show that the vehicle and suspension type influences the overall response of the bridge, as is the condition of the road approaches to the bridge. Interpretation of individual bridge and vehicle responses in the frequency domain has also proven to be critical in understanding their dynamic interactions.

While benefits are ultimately dependent on the final-year outcomes, substantial potential savings on strengthening and replacement of structures on the network can be achieved. Based on an average I-girder bridge replacement cost of $2 million and strengthening cost of $500,000, it is estimated that works totalling $20 million could be re-prioritised or deferred.

Deck unit bridge deck analysis under live load

There are over 1,900 transversely stressed deck unit bridges on the TMR network. This family of bridges is unique in its design and performance with a low level of transverse post-tensioning, upright external units and no shear-keys. While standard assessments indicate overloading, the observed actual in-service performance does not necessarily indicate distress. Accurate modelling of this family of bridges has been difficult to achieve.

Several milestones have been achieved in the first two years of this research project, including load testing and continuous monitoring of an in-service bridge of this type and destructive testing of individual decommissioned deck units. Results confirmed that these bridges behave in a similar fashion to solid reinforced concrete slabs and perform better than current assessments (indicating better alignment with observed condition and performance). Test results suggest that individual deck units have significantly higher ultimate shear and bending capacities than predicted in previous theoretical assessments. These results provide TMR with greater confidence in processing permit applications as well as undertaking a review of current restrictions on the network.

The final year of the project (2015-16) involves destructive testing of a decommissioned deck unit bridge to investigate bridge performance under ultimate loading. Outcomes of this project will be incorporated into existing assessment/design TMR guidelines as well as the permit process for all transversely stressed deck unit bridges on the whole network. Given the large number of bridges of this type on the network, substantial savings and greater productivity may potentially be gained through the research, such as elimination of conservative restrictions on existing bridges on key routes, increased freight movements and better risk management. Development of internal staff skills and capabilities in undertaking the bridge load testing, instrumentation and assessment has been achieved through this project. There are approximately 260 deck unit bridges designed and constructed during the 1960s. Assuming that the research will eliminate the need for strengthening of bridges of this era alone, a conservative estimate of savings is $10 million .

- Load testing and monitoring of in-service and decommissioned structures confirm better than predicted performance
- This could help to ease or eliminate load restrictions on key routes, improving network efficiency
- Future calibration of theoretical structural models will enhance the accuracy and efficiency of load rating assessments
- Potential cost savings on strengthening amounts to $10 million

Structures

Structural health monitoring of existing bridges

TMR currently manages structural health through an inspection program with inspection frequencies dependent on the risk profile and/or strategic importance of the structure. This does not necessarily provide the asset management team information on how at-risk structures are behaving or deteriorating in response to the perceived hazard (e.g. under heavier and/or more frequent vehicle loading, in response to flood events).

An effective program of health monitoring will increase TMR's knowledge of the performance of existing at-risk bridges. The outcome of an effective health monitoring program will lead to a better understanding of bridge and network risks, enabling TMR to better manage risks and, as a consequence, utilise limited resources more efficiently. With better information, practical, defendable decisions can be made regarding justification and prioritisation of strengthening as well as permitting increased freight on particular routes. Furthermore, response to large-scale events (e.g. flooding) can be more effectively targeted. Whilst direct cost savings are not easy to quantify, the outcomes of the project will underpin the work undertaken in instrumenting and testing of bridges in the other related projects.

Specifically, the following benefits can be achieved:

- improved safety of network
- increased confidence
- reduced costs.

- Effective health monitoring of existing bridges leads to a better understanding of bridge and network risks
- Improved information on structural health increases safety and freight allocation across the network
- Guidance for future instrumentation projects and guidelines have been delivered

The goal of this two-year project was to develop guidelines for TMR outlining applicable health monitoring technologies for use on the network. It has also provided TMR with guidance on the selection of the most appropriate technologies to use in undertaking load testing and instrumentation of existing structures. The guidelines were delivered in July 2015.

Review of the TMR bridge asset management system

The TMR Bridge Inspection Manual (BIM) embodies the TMR asset management framework for bridges and major culverts, establishing a state-wide policy and documenting accountabilities along with procedures for systematic inspection, reporting and data management requirements.

The manual has not been updated in 10 years and it is recognised that a review and update is needed. It does not fully represent all bridges or other significant highway structures such as tunnels, metal culverts, structures supporting large signage and new materials.

The purpose of this three-year project is to evaluate the existing TMR Bridge Management System against current and future needs and requirements related to the integration of key data. The project will review the existing BIM to address:

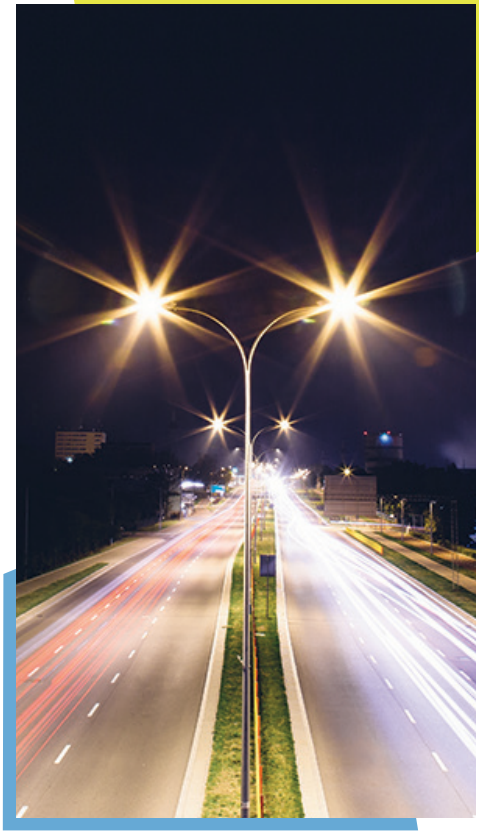
- all relevant structure types (bridges, culverts, tunnels, retaining structures, scour/coastal protection, variable message signs and other gantry structures)
- management of unique/significant complex structures
- risk management
- development of an integrated asset management system.

Associated work undertaken by ARRB for TMR feeds into the asset management review, in particular a review of inspection frequency will ultimately have direct cost savings once implemented. The publication of the revised manual is progressing with several parts finalised. Specifically, the asbestos policy and procedures were an early win during the first year of the project as it addressed a very specific risk to TMR.

One of the key elements of the project is to benchmark existing systems against the asset management framework promoted in ISO 55000. This will be completed in Year 3 (2015-16).

- Ongoing project to evaluate and review all aspects of the TMR Bridge Inspection Manual
- Benchmarking of existing systems against international standards, and integration of latest technology and practices
- Value added through increasing the review period for Structure Management Plans (SMPs), more efficient inspections and enhanced risk management

Other



A further six projects are funded in the fields of network operations (three projects), road safety (two projects) and heavy vehicle management (one project), totalling roughly 15% of the total program investment.

While not the core focus of the NACOE program, these projects have still been able to realise significant benefits to TMR and assist with capacity building and fostering partnerships across the organisations.

TMR recognises the importance of these areas to delivering beneficial outcomes to the department and Queensland through a number of mechanisms, including:

- driving savings through improved network efficiency by incorporating managed motorways and by adopting best practice modelling of congestion in urban areas
- cutting the road toll by targeting key crash types and investigating cost-effective techniques to minimise serious and fatal injuries
- recognising dangerous links in the network and targeting these locations with road safety treatments, such as the use of wide centrelines on the Bruce Highway
- streamlining heavy vehicle policy to remove barriers to industry while delivering the best outcomes for the network as a whole.

Through NACOE, a number of projects will also advocate the use of smarter technology on Queensland roads.

Investigate road user and operational benefits to TMR by improved speed management

TMR has upgraded many of its motorways to managed (smart) motorways, enabling improved operation and performance outcomes. ITS-enabled services such as variable speed limits (VSL) allow better control of vehicle flows and help to improve safety and minimise congestion, particularly during times of high demand or incidents.

However, the current algorithms rely on manual rather than automated operation, which can result in delays to operational response and means the full benefit of the VSL tools are not being realised. With an extensive managed motorway upgrade program planned for South-East Queensland over the coming years, it is essential that the technologies are optimised to deliver maximum motorway productivity, as well as improved operational efficiency (and cost savings) for TMR.

This research has supported assessment of motorway detector health and algorithm configuration in order to prepare the algorithms to an acceptable quality for field testing. The performance of the algorithms during a partially automated trial was then evaluated, demonstrating significant improvements in incident detection rates and response times. Analysis at a key bottleneck site within the trial showed an additional 3.6% increase in throughput above the average annual throughput growth of 3.2%, with a corresponding increase in average speed of 8% at the same site. Ongoing work is required to undertake and evaluate a fully automated trial.

- Speed management on smart motorways can improve vehicle flow and safety
- Current approaches do not take advantage of automated technology and variable speed limit tools
- Use of latest technology could improve motorway throughput by 3.6% and average speed by 8%

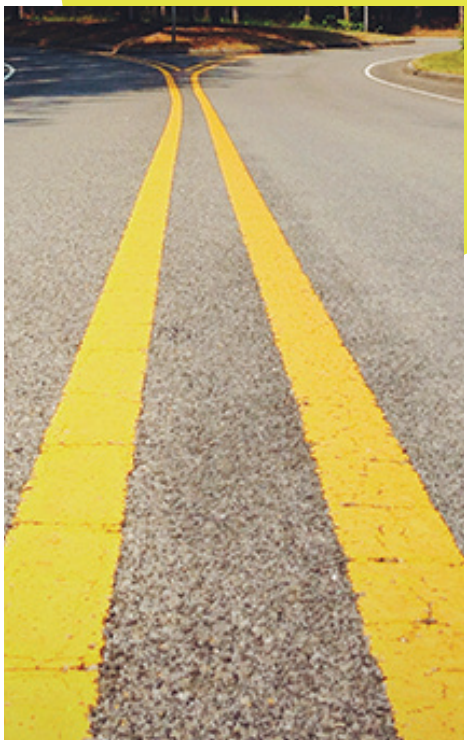
Measuring the cost of congestion on a multi-modal basis

The purpose of this project is to produce a methodology for estimating congestion costs associated with on-road buses, freight, bicycles and pedestrians. This work will enhance TMR's cost-of-congestion estimate, which is based on previous ARRB work and the national performance indicator (NPI) reporting system.

The TMR cost of congestion currently includes freight; however, the estimate is based on a single heavy vehicle percentage for the network, and there is interest in breaking down the costs by roadway and user. Including other trip types ensures the cost takes into account all trips impacted by road-based congestion.

Current TMR cost-of-congestion tools require some refinement to capture these trip types, allowing for a more complete understanding of user costs. Understanding the economic cost of traffic congestion is an important part of developing the appropriate response strategies.

The project continues into 2015-16 where the focus will be on enhancing the cost-of-the congestion tool, enabling this to be used to inform investment, benchmark performance, and to test and evaluate the effectiveness of congestion reduction options. This will facilitate better-informed decision making for road managers.



Review of in-service test for road friendly suspensions (RFS)

Heavy vehicles fitted with road friendly suspension are afforded mass and access benefits not available to vehicles that do not have RFS on the basis that RFS reduces pavement damage. However, evidence shows that the performance of RFS does degrade over time, mainly due to service degradation of shock absorber damping. To continue to derive the benefits of RFS throughout its life, it is necessary to monitor and correct the service degradation of RFS.

There has been no in-service test for RFS. Instead, visual inspections of the bushes, airbags and tyres are undertaken to assess the health of the vehicle's RFS. This project has reviewed the options for developing an in-service test and prioritised the solutions that will best allow for the continued realisation of benefits from the use of RFS across the network.

The following engineering solutions have been identified for further investigation:

- on-board scales (high and low frequency)
- commercially available products for measuring shock absorber performance
- tyre pressure sensors
- electronic braking system (EBS) control modules.

The take-up of these technologies is much greater now than when the last in-service complete review was conducted in 2008. Many are commonplace and gather data that can be used to measure suspension performance. The next stage of the project will prove as a concept the use of such technologies to quantify suspension performance related to road-friendliness as defined in Vehicle Standards Bulletin VSB11.

In addition to this, truck simulation models have advanced and now include the ability to estimate dynamic loads. Simulation models offer a solution to overcome the practical issues (e.g. road inputs, unknown payload mass) that have previously prevented an in-service compliance standard from being developed.

Heavy vehicle interception site guidelines and audit

With the introduction of larger heavy vehicles (including road trains) on the Queensland rural road network, it was necessary to revise the design guidelines for heavy vehicle interception sites. Interception sites are necessary to prevent overloaded vehicles and to ensure compliance with heavy vehicle regulations.

The project found that five different types of interception sites are used across the state, and recommended changes to the standard designs based on average annual daily traffic volumes. The new guidelines will allow for safer entry and exit from the sites and lead to more efficient inspection practices.

Reducing fatal and serious injury crashes on the Queensland network

Network-wide review of head-on, run-off-road and out-of-control crashes in Queensland

During 2007-11, 69,533 injury crashes were recorded on Queensland roads, with 40% of those being fatal or serious injury crashes. This project conducted a review of head-on, run-off-road and out-of-control crashes on the Queensland network to determine their severity, identify their causes, and to recommend mass treatments to reduce crash risk and severity.

The literature review and data analysis revealed that head-on injury crashes were the most severe of the crash types, with 61% resulting in a fatality or serious injury. All three crash types were greatly affected by many factors including primary vehicle controller (males accounted for 70% of head-on injury crashes), road-rule adherence, horizontal curvature, lighting and time of day.

Recommended cost-effective treatments included separating opposing traffic using wire rope barriers (50% reduction in fatal crashes in a Swedish trial, largely eliminating head-on crashes), wide centreline treatments (75% reduction in head-on crashes on the Bruce Highway), shoulder rumble strips (40% reduction in run-off-road crashes), clear curve delineation and advanced warning for road users.

Monitoring and evaluation of safety treatment performance on the Bruce Highway

The Bruce Highway has previously been identified by AusRAP as one of the most dangerous roads in Australia, accounting for one in six deaths (17%) on the entire national network and accounting for half of all Queensland casualty crashes and 61% of deaths during 2005-09. In addition, AusRAP reported in 2013 that 45% of the Bruce Highway achieved only a 1 or 2 star rating for road infrastructure safety.

The effectiveness of safety improvements on the Bruce Highway are being investigated as an ongoing project. The first year of the project examined the effectiveness of wide centreline treatments, and (provisionally) found that crash reductions in the order of 30% can be realised from installing wide centrelines. This provisional result was based on statistical analysis of data for 2.5 year before/after periods for wide centreline treatments on two Bruce Highway sections.

The effectiveness of other installed treatments on the Bruce Highway including audio-tactile line markings, painted median treatments and barriers will be studied in 2015-16.

Based on historical crash data and crash costs, the estimated 30% reduction in fatal and serious injury crashes by installing wide centreline treatments along the full length of the Bruce Highway could potentially translate to crash cost savings in the order of $150 million per year. Implementing a combination of treatments targeted at high-risk crash types and in high-risk locations as part of the Bruce Highway Safety Package is expected to deliver further significant reductions in road casualties over the next 10 years and beyond.

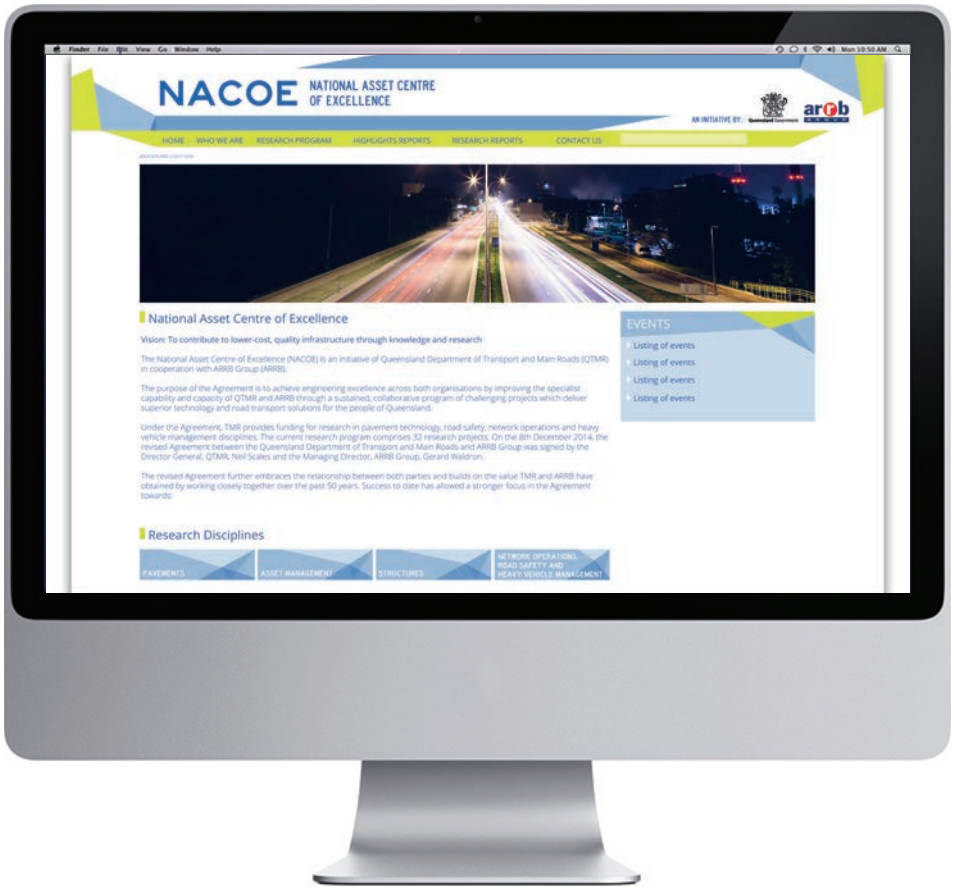
- These crash types have particularly severe outcomes in terms of death, serious injury and economic cost
- A number of factors increase the risk of these crashes
- Treatments including wire rope barriers and wide centrelines may lead to several hundred million dollars of savings
- Bruce Highway records the highest number of serious and total crashes on the Australian road network
- Wide centreline treatments are estimated to cut fatal and serious injury crashes by 30%, or up to $150 million per year if extended across the length of highways

Other Projects

NACOE website launch

In 2015-16, a new NACOE website will be launched. It will provide access to all key reports and the latest developments across the NACOE program.

A key focus of the website will be the dissemination of key findings from the program so that the potential benefits of each project can be accessed by a wide audience.



Get involved

How to get involved

The NACOE program runs on a rolling four-year basis, with projects generally spanning 1 to 3 years. The upcoming year's program is discussed early in the new year.

The program relies on the input and collaboration of ARRB Group, TMR and industry personnel to develop ideas for projects across the four key discipline areas of pavements, asset management, structures and other (network operations, road safety and heavy vehicle management).

Any suggestions for projects can be submitted through the NACOE website, at www.arrb.com.au/nacoe or through the NACOE email address nacoe@arrb.com.au

Feedback and contact details

The NACOE Agreement Managers can be contacted with any feedback or to make enquiries regarding the program or specific projects.

Peter Evans
Deputy Chief Engineer - Pavements, Materials & Geotechnical
Queensland Department of Transport and Main Roads
35 Butterfield Street, Herston QLD 4006
(07) 3066 9611
peter.a.evans@tmr.qld.gov.au

Carlos Rial
Regional Manager - Queensland/NT
ARRB Group Ltd
123 Sandgate Road, Albion QLD 4010
(07) 3260 3535
nacoe@arrb.com.au

NACOE
NATIONAL
ASSET CENTRE
OF EXCELLENCE

Notes

To contribute to lower-cost, quality infrastructure through knowledge and research

arrb GROUP

Queensland Government

NACOE CONTACT DETAILS

ARRB Group | 123 Sandgate Rd | Albion QLD 4010
Australia | P: +61 7 3260 3500 | E: nacoe@arrb.com.au

Queensland Department of Transport and Main Roads