NZ TRANSPORT AGENCY
WAKA KOTAHI

AGENDA NO. 140724-03

VAC PAPER

Paper no:	140724-03
Meeting date:	24th July 2014
Prepared by:	Gerhard Van Blerk (National Technical Advisor)
Recommended by:	Kevin Reid (National Manager Network Outcomes), John Donbavand, (National Pavements Manager) and Peter Simcock (Manager Project Services)
VAC function:	Approve
Subject:	**Waikato Expressway Huntly Section: Pavement Specification**

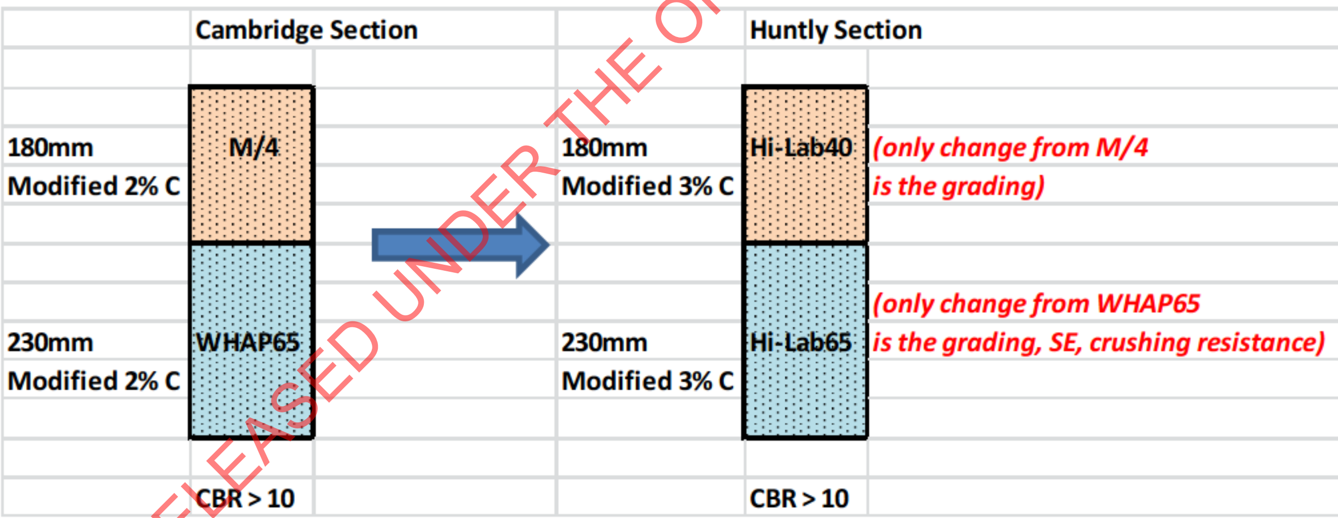
PURPOSE

1. Request approval to specify the design methodology in the Pavement appendix of the Principals Requirements (PR's) for the Huntly Section of the Waikato Expressway. The purpose is to advance a further step from the Cambridge Section PR's by specifying the Hi-Lab design methodology - which in essence is a change to the grading and cement content for the base and subbase layers – with improved aggregate quality for the subbase layer.

SUMMARY

2. The Huntly Section of the Waikato Expressway is progressing as a Design and Construct type of contract with the Pavements Section currently being developed.

3. The Pavement PR's for the Huntly Section will be the same as the Cambridge Section awarded last year except for the following three changes (see diagram below):



- Cement content: cement content for the base -and subbase layers will increase from 2% to 3%.
- Aggregate grading: the Hi-Lab40 and Hi-Lab65 specify a coarser grading, which forms the foundation of the design/construction technique.
- Improved quality for the subbase layer: the Hi-Lab65 subbase specifies stricter aggregate parameters for the sand equivalence (SE) and crushing resistance.

4. The actual changes proposed to this Pavement appendix when compared with Cambridge are minor and do not depart significantly from other previously accepted pavement PR's in terms of specifying pavement layer thickness and supporting CBR (CBR = 10%). The risk profiles and specified outcomes (e.g. deflections, roughness, etc.) also remain the same. However the proposed minor changes will have a huge impact on the pavement performance.

5. Based on a whole of life analysis (40 year) the Hi-Lab design/construction proves to be a value for money and cost effective option. It is estimated that the Hi-Lab will cost $2-$3 million more to construct but it will deliver a benefit of $13-$15 million. In terms of the Economic Evaluation Manual this represents a **BCR of 6.9** (equal to a BCR of 22 once it is risk adjusted). Observed performance in the field and laboratory test results to date show that the Hi-Lab design/construction technique is technically sound. Again, this will be described in more detail below.

6. Industry support more prescriptive PR's as it provides a level playing field for pricing. In addition, experience has shown us that "innovation" is limited to promoting **thinner** pavements with no other innovation than transferring additional risk to the NZ Transport Agency and negotiating after contract award a variation for a more robust type of pavement.

7. More prescriptive pavement PR's also simplify the tender evaluation process and reduce the subjectivity when applying Tender Cost Adjustments as pavement design is not an exact science. It should be acknowledged that the art of pavement design and the behaviour of materials (aggregate) consist of multiple variables at play and are not always well understood and quantified.

8. The Hi-Lab design and construction technique is based on "full" stone interlock, which in turn maximizes the load transfer. The end result is the optimization of the inherent stone (aggregate source) potential, taking full advantage of this scarce resource. The product can be viewed as "environmentally friendly" by taking full advantage of the resource potential and not allowing the finer particle sizes within the grading to dictate performance (stones floating in a matrix of fines).

RECOMMENDATION

9. That the VAC

Supports the Hi-Lab design methodology to be included in the Principal's Requirements for the Huntly Section of the Waikato Expressway; subject to completion of the Peer Review of the Economics by Road Science. DMT agreed to an increase in supervision and random verification testing to support the change to the Principal's Requirements.

BACKGROUND

10. The Huntly section comprises approximately 15km of four lane expressway between the completed Ohinewai (to the north) and Ngaruawahia (to the south) sections of the Waikato Expressway.

11. The project is progressing as a Design and Construct contract model with the Pavements Section currently being developed.

12. A common issue within the Design and Construct model is the Contractor's proposal of a pavement that only marginally complies with the requirements and which consists of thin pavement thicknesses and reduced aggregate quality. It is of interest to note that all parties (NZ Transport Agency, consultant and contractor) involved with these contracts, agree post award that the proposed

pavement designs is a high risk. As a result "Enhanced Pavements" are post-award renegotiated in a non-competitive market (Refer attached Memo RON's Cambridge Section: Principals Requirements for Pavements). This practice can be prevented by being more specific with the pavement PR's.

13. The NZ Transport Agency has a mandate under the Strategy Plan and NLTP to deliver value for money on all projects, present and future. Value for money in all that we invest in and do is an ongoing challenge for us and our partners that require new ideas and approaches. To assist us in the delivery of these outcomes, we need to learn from past experiences and improve where opportunities arise. For capital projects the principals requirements (PR's) are very important as it provides a small window of opportunity for the client to specify minimum requirements.

14. Average to poor pavement performance has been observed from historic large capital projects (Waikato Expressway Projects, Route PJK, Alpurt) within the Waikato, Tauranga and Auckland. Within the first 5 to 15 years, maintenance cost specific to these projects has been and continue to be very significant. Poor performance are as a result of steep rut progression, cracking, pumping of fines and pavement failure, which are all triggers initiating early maintenance intervention.

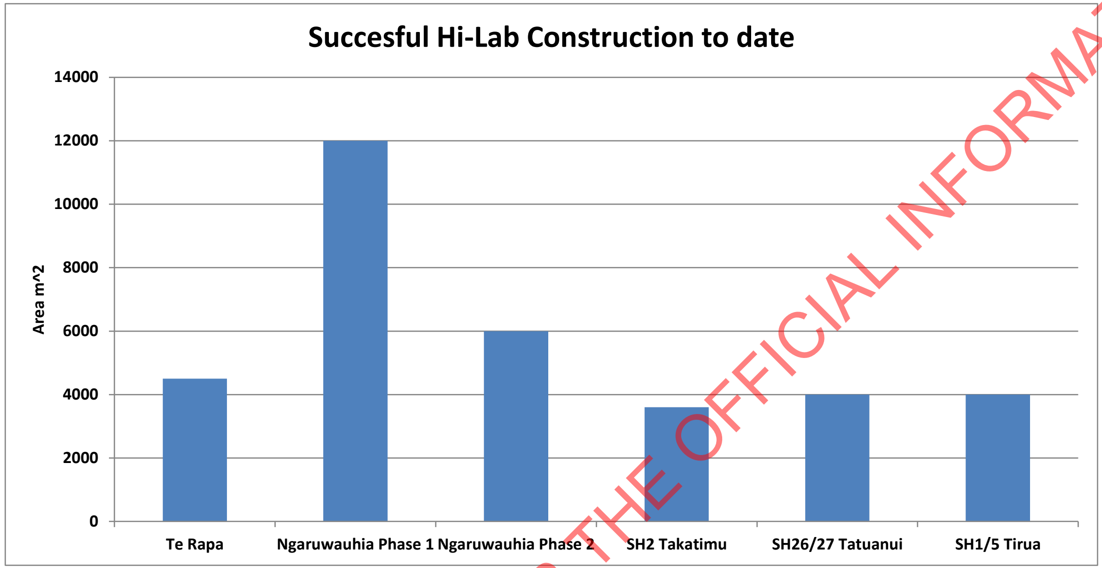
15. The present flat line maintenance budget means that a similar performance on the Huntly Section is unacceptable. However, an opportunity exists to improve on pavement PR's and build on the Cambridge Section reducing the long-term risk of poor performance.

16. The Hi-Lab construction technique is an alternative design and construction technique to road construction that incorporates lessons learned on existing pavement failures and seeks improved performance at reduced whole of life cost.

17. An extensive amount of Hi-Lab has been constructed to date. It originated in 2008 as a rehabilitation treatment. Since then the Hi-Lab construction has been successfully constructed on parts of the large capital and RON's projects such as Ngaruawahia, Te Rapa, Taupiri Link (Ngaruawahia Stage 1), SH26/27 Tatuanui Round-about, SH1/5 Tirua Round-about and SH2 Takatimu Drive. As a result of these trials the main suppliers (Fulton Hogan, Higgins, Downers, Fletchers, Swaps, Schicks) have already been exposed to this construction technique. Feedback post construction has been positive.

(John Donbavand completed an interview with FH after completion of the Te Rapa section and their feedback was positive).

18. Within the last 3 year more than 40,000 m2 have been completed as capital projects for high traffic volumes within high stress conditions (see graph below). To date these pavements are performing well with no visual distress (cracking, deformation, etc.).



19. In addition, more than 200,000 m^2 have been completed as rehabilitation works within the last 6 years and their performance is also very good.

$ FINANCIAL (VALUE FOR MONEY)

20. We have carried out an economic assessment of the Hi-Lab pavement following the Economic Evaluation Manual and obtained a BCR of 5.6 and 9.6 (risk adjusted). This means that Hi-lab is a cost effective alternative over the whole of life cycle..

21. To ensure a robust assessment the analysis took a conservative approach and some of the financial benefits (reduced maintenance cost) were excluded. In addition, inflated Hi-Lab costs were used for the aggregate. They were inflated as they were based on rates obtained from small quantities.

22. The initial cost of the Hi-Lab design is marginally greater but improved performance with reduced risks make this option the best whole of life option. It is estimated that the Hi-Lab will cost $2-3 million more delivering benefits of $13 - $15 million.

23. The Hi-Lab up-front cost is higher than other pavements for the following two reasons:

- The Hi-Lab65 sub-base layer, being a better aggregate quality compared to a WHAP65 product, is more expensive to source due to the tighter grading envelope. This factor constitutes the biggest cost difference.
- The extra cement quantities, going from 2% to 3% and the Hi-Lab 40 base layer compared to a modified M/4 is very small. It is expected with increased quantities the M/4 and Hi-Lab40 can be produced at similar costs.

24. The following factors are a summary of the whole of life analysis:

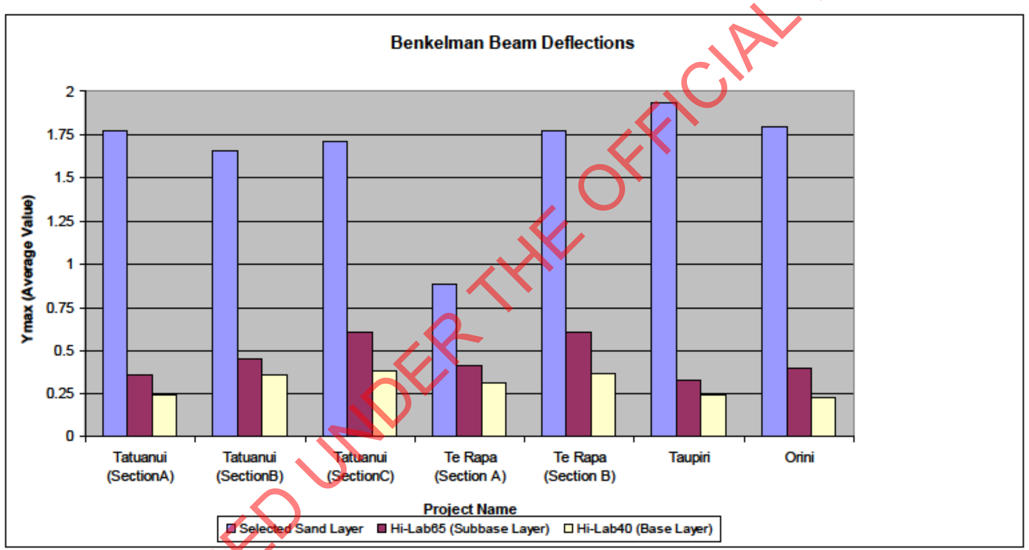
- The majority of the benefits are due to savings on the vehicle operating cost (VOC), reduced roughness and reduction of CO_2 emissions. The Hi-Lab pavement is more rigid and has less pavement deflection so there are reduced rolling resistance as a consequence of this.
- Annual routine maintenance cost for both pavements options (scheme and Hi-Lab) were excluded, the Hi-Lab option can be seen as a lower maintenance option with increased benefits. However, these benefits were not included in the analysis.
- Noise, safety and travel time costs were also excluded for the analysis. Both options assumed OGPA surfacing, which is cost neutral and because of OGPA texture was also excluded.
- Inflated square metre (m^2) rates were used for the Hi-Lab, as these rates were based on small quantities. Again, these benefits were excluded to limit criticism and provide a more robust analysis.

25. The detailed economic evaluation and Opus report is attached.

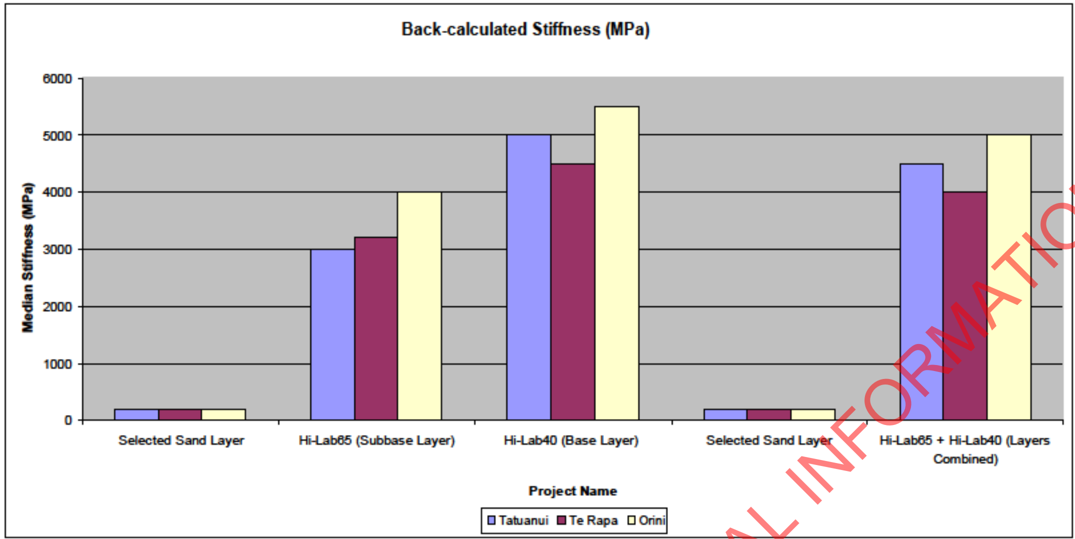
TECHNICAL (PERFORMANCE)

26. Over the last 6 years the performance parameters of the Hi-Lab have been tested extensively (field and laboratory). Through this process the design specifications and parameters has been validated and verified. The following are typical results obtained from these tests methods:

- **Falling Weight Deflectometer (FWD) pavement strength and deflections** – Peak deflections and back-calculations of the Hi-Lab layers shows the product is achieving the design strengths and stiffness. These exceptional results are achieved through a stone-on-stone interlock, which forms the basis of the design theory. The graph below shows the reduction in peak deflections and improved backcalculated stiffness with the addition of each layer for various capital sites. These results validate the design specifications and notes.



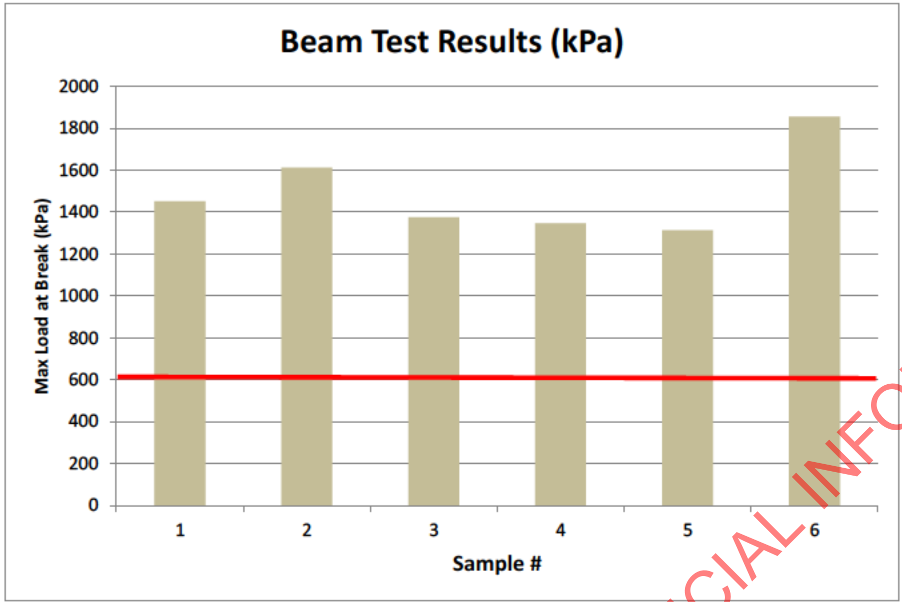
In summary, the results show an impressive reduction in maximum deflections from 1.75mm to 0.3mm with the successful construction of each additional layer. This is as a result of optimised load transfer though stone interlock.



Again, the design criteria are validated through post construction backcalculations which shows each Hi-Lab layers achieving design stiffness in the field.

- **Beam Fatigue Tests –** these tests were completed from samples taken in the field to assess actual field performance. The purpose of the beam fatigue tests was to ensure the design specifications (fatigue criteria) were achieved in the field. The pictures below shows the test samples removed from the field, the test method and typical test results. Test results show the Hi-Lab exceeding design stiffness values, thus ensuring the layer operate below 50% of the maximum horizontal tensile fatigue. Therefore, the pavement will not be overstressed during its design life. ***When constructed correctly the results points to the performance of a perpetual pavement.***


111910_11_11 HiLab 65 +3% cement



Note: the red line shows the minimum design criteria to prevent over stressing of the layer. The results clearly shows the material perform well above the design criteria.

- **Indirect Tensile Strength (ITS) Core Samples –** the ITS test is a very harsh test to perform on a weak cemented material, exposing the sample to tension and not compression. The Hi-Lab has a limited amount of cement (3% C) but performed well above expectation as a result of the stone interlock. The pictures below shows the extraction of core samples in the field, the test method performed in the laboratory and typical performance results.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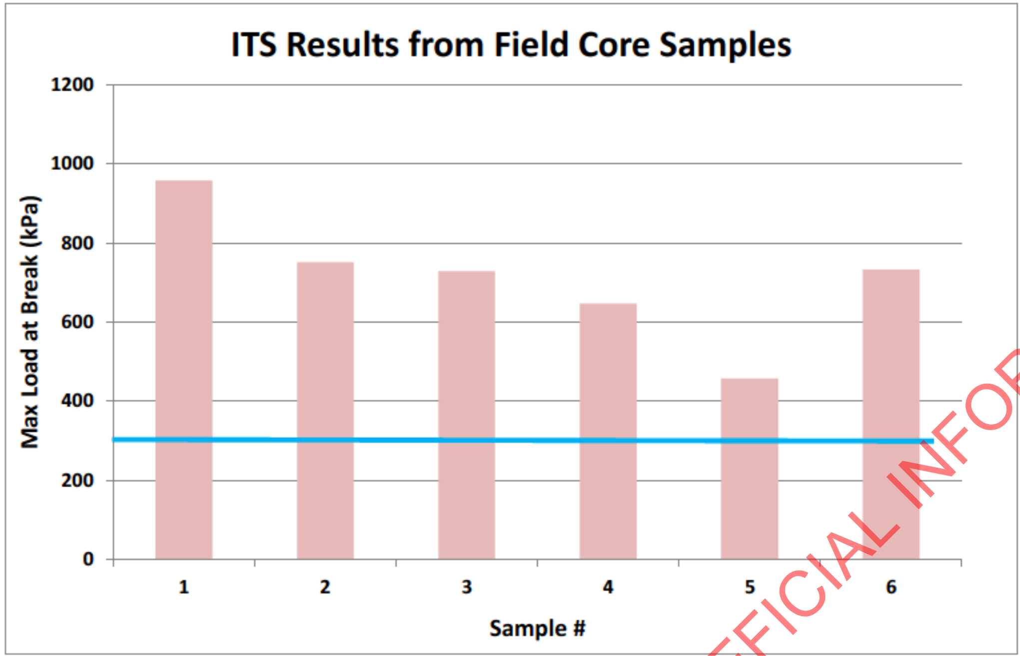

Note: the blue line shows the minimum design criteria to prevent over stressing of the layer. The results clearly shows the material perform well above the design criteria.

- **Concrete Cube Compression Test –** field samples obtained from the beam test is used to complete compression test. The purpose of the tests was to assess the strength gain achieved from the stone interlock and the influence of the 3% cement. The pictures below show the test method, crushed sample and test results.


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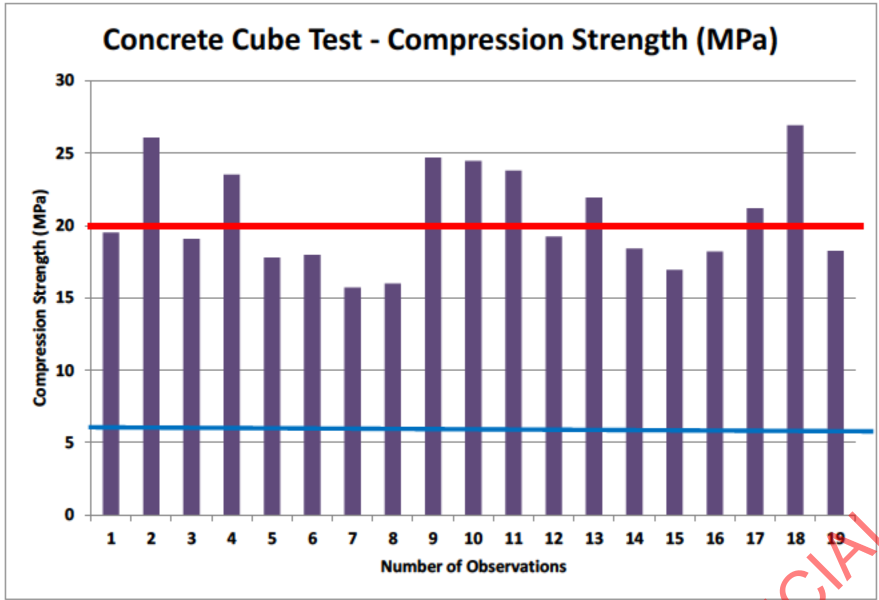

The red line shows the average compression strength test results for a total of 19 Hi-Lab cubes. It is extra ordinary to achieved 20 MPa from a material containing 3% cement as these values are typical of 15% cement. The blue line shows typical results achieved from M/4 material with 3% cement*. **This clearly shows that the same material with the same cement content but different grading has a hugely different result.*** The compression strength achieved from M/4 material is typically 6 MPa, since the strength is dictated by the cemented fines matrix and not the stone interlock. In comparison to Hi-Lab generate three to four times the compression strength achieved from M/4. These results validate the hypothesis that the achieved strength are as a result of the stone interlock. This is shown by the picture above of stone fracture under compression. Again, this is only possible with "full" stone interlock.

RISKS

27. The basis of the submission is to reduce maintenance risk to the NZ Transport Agency. This can be achieved by improving the pavement PR's based on past learnings. Doing nothing is seen as a greater risk. This is a step change for the NZ Transport Agency which will require greater involvement and ownership.

28. The Hi-Lab will bring improved quality but this will only happen if construction observation/ quality control are performed. To achieve this NZ Transport Agency may have to invest in additional Q&A testing and supervision.

COMMUNICATION AND ENGAGEMENT

29. This is a technical decision that does not require significant media involvement but the construction industry will need briefing..

ATTACHMENTS

There are two attachments:

- Hi-Lab Draft Specification and Notes
- Economic Evaluation Manual, Whole of Life Analysis (B/C) and Opus Summary Report
- Memo *RON's Cambridge Section: Principals Requirements for Pavements*

16 Critical Questions:

Problem	Benefits	Strategic Response	Consistent
Is it clear what the problem is that needs to be addressed? (both the cause and effect)	Have the benefits that will result from fixing the problem been adequately defined?	Have a *sufficient* range of strategic interventions been explored? (demand, productivity & supply)	Consistent with the strategic Interventions , have a *reasonable range of project Options* been analysed?
Yes Maybe No ?	Yes Maybe No ?	Yes Maybe No ?	Yes Maybe No ?
Is there evidence to confirm the *cause and effect* of the problem?	Will the KPIs that have been specified provide *reasonable evidence* that the benefits have been delivered	Is it clear what strategic interventions are proposed and the rationale for their selection?	Is the proposed solution specified clearly and fully? (all business changes and any assets)
Yes Maybe No ?	Yes Maybe No ?	Yes Maybe No ?	Yes Maybe No ?
Does the problem need to be addressed *at this time*?	Are the KPIs both *measurable* and *totally attributable* to this investment?	Are the proposed interventions the most effective response to the problem? (comprehensive and balanced)	Is the proposed solution the *best* way to respond to the problem and deliver the expected benefits?
Yes Maybe No ?	Yes Maybe No ?	Yes Maybe No ?	Yes Maybe No ?
Is the problem specific to this investment? (or should a broader perspective be taken)	Are the benefits of high value to the organisation? (furthering its objectives)	Are the proposed interventions *feasible?*	Can the solution really be delivered? (costs, risks, timeframes, governance, etc)
Yes Maybe No ?	Yes Maybe No ?	Yes Maybe No ?	Yes Maybe No ?