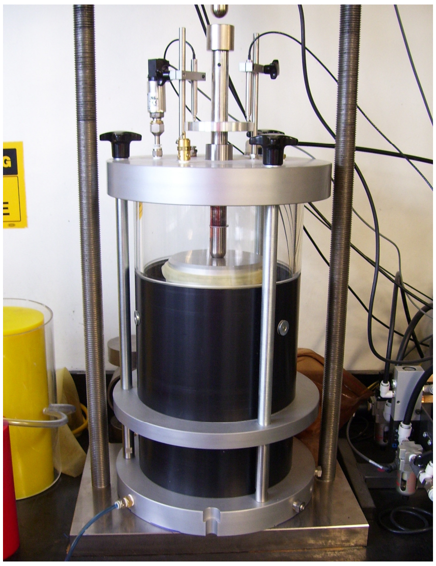
ROAD SCIENCE
LEADING PAVEMENTS TECHNOLOGY



Huntly Section: Pavement Economics

Review of s 9(2)(a) [redacted] (Opus) memo dated 2 July 2014

Quality Assurance Statement

Prepared By: [redacted] **PhD**
Technical Manager - Pavements
Road Science

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Amendment Register

Date	Changes	Rev

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1 Introduction

The 2 July 2014 memo by [redacted] details several assumptions in the economic analysis of two different pavement options. A few of these assumptions are questioned and discussed. However, despite questioning these assumptions the author still favours the alternative Hilab option primarily due to the lower risk of early pavement failure rather than a reduction in vehicle operating costs.

2 Pavement Deflection Assumptions for Calculating Vehicle Operating Costs

There are two pavement types being considered both are three layer cement stabilised pavements totalling 620mm over a 650mm subgrade improvement layer with a CBR of 10% on a subgrade CBR of 3.5%. The only difference is for the "alternative option" the top 400mm of one of the pavements uses Hilab with 3% cement while the other "base option" all the three layers are standard aggregates with 2% cement. Flexural Beam Tests with Hilab show double the strength than with the same cement content using standard aggregate. Therefore assuming twice the strength with the Hilab the following deflections are calculated:

Modulus Stiffness of the top 400mm of the pavement (underlying material the modulus values are unchanged)	Pavement Deflection, Estimated from CIRCLY
10,000 MPa	0.41 mm
5,000 MPa	0.51 mm
2,500 MPa	0.62 mm
1250 MPa	0.76 mm

From the analysis it is shown that halving the strength/stiffness results in a 0.1 mm increase in thickness. This difference in deflection is small compared with the 0.4mm increase in pavement deflection assumed in the Opus memo. Therefore, the difference in vehicle operating costs are considered to be smaller that is calculated in the Opus report. However, the base option will likely return to unbound within 10 years and thus the pavement deflections will increase to the 0.76mm while the alternative option should remain bound and the deflections will remain around 0.5mm.

3 Risk of Early Failure

I support the risk profile numbers give by Opus as shown below:

Table 5: Risk Probability Scenarios

Scenario	Risk Probabilities		Comment
	Base Option	Alternative Option	
1	0.10	0.05	**Early Failure** - within 20% of design life (road fails in **year 6**, replacement lasts normal design life)
2	0.20	0.10	**Premature Failure** - 20-70% of design life (road fails in **year 11**, replacement lasts normal design life)
3	0.50	0.5	**Predicted Failure** - 70-130% of design life (road fails in year 28, replacement lasts beyond analysis period)
4	0.15	0.25	Late Failure - 130-150% of design life (road fails in year 35, replacement lasts beyond analysis period)
5	0.05	0.10	Long Life Failure – beyond 150% of design life (road fails in year 38, replacement lasts beyond analysis period)
Sum	1	1	

The main reason for supporting a lower risk profile for the Hilab Alternative Option is the significantly greater strength and thus ability to remain bound over the design life. A design criteria developed from NZTA research requires the tensile stress at the base of a stabilised layer to be less than half the beam flexural tensile strength to ensure the stabilised material remains bound. The Figure below demonstrates this design check.

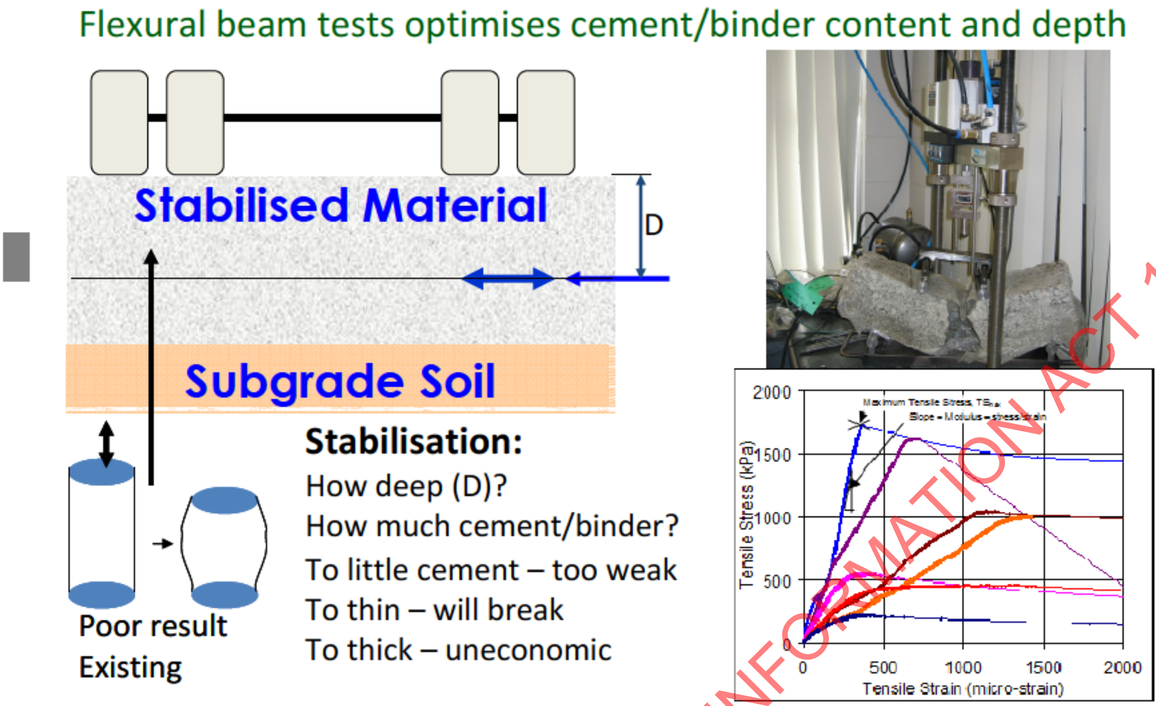

Figure – Flexural beam tests and horizontal tensile stress design check.

Assuming no bond between the stabilised layers (see photo below) CIRCLY was used to calculate the tensile stress at the base of the stabilised layer for both the base and alternative option. This calculated tensile stress was compared to typical tensile strength of the base (2% cement with M4 aggregate) and alternative (3% cement with Hilab aggregate) to determine whether or not the material will return to an unbound state. This analysis found that the base option is likely to return to unbound and thus a shorter life than the alternative which will remain bound over the design life.

	Tensile Stress at base of layer (kPa)	Typical Design Tensile Strength (note this is halve beam strength or equal to ITS)	Will the stabilised material return to unbound?
Hilab – Alternative Option (5000 MPa)	601 kPa	800 kPa	No
Base Option (2500 MPa)	492 kPa	400 kPa	Yes

Figure – Photo of debonding between the two stabilised layers.

4 Summary

Overall I support the economic analysis undertaken in the Opus memo, except the benefits for a reduction in pavement deflection for the Alternative Option will only occur after 10 years when Base option returns to an unbound state.