Thorpe Road

(SH1 RP664/6258–6530)

NZ Transport Agency
Central Waikato Network Outcome Contract
17 February 2016

Pavement Renewal Report

Downer
Relationships creating success

Prepared for: s 9(2)(a) [redacted], Manager Taupo, Downer

Prepared by: s 9(2)(a) [redacted], Technical Manager – Pavements
BE(Hons), PhD

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Reviewed by: s 9(2)(a) [redacted] Opus

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Date	Changes	Rev

Contents

Executive Summary

This report presents the results of a site investigation and pavement renewal design for a 300m length of pavement on SH1 near the Thorpe Road intersection south of Atiamuri. The project is part of the Opus Central Waikato Network Outcome on Contract on behalf of NZ Transport Agency for the 2015/2016 construction season.

The site location is defined as SH1 624 RP 6258-6530.

The main driver for rehabilitation is the severe flushing in the wheel tracks that occurs in summer due to the high temperatures. This section has 70 to 100mm thick seal layer with a binder stone ratio of 18.2 resulting in unstable surface layers, and reducing seal life in the last 10 years. The most recent sandwich seal lasted only 1 month before flusing occurred subsequent reseals are also expected to have short lives and thus to increase the seal life to provide adequate texture and skid resistance a pavement renewal is required.

Test pits (see Figure below) show 550mm cover to a pumice subgrade where the top 100mm is existing unstable seal layers. The insitu aggregate is Dacite AP40 and the RLT test found to have very poor rut resistance. This poor rut resistance of the insitu Dacite aggregate at 6.6% moisture content (considered dry) governed the design resulting in thick granular overlays to prevent the Dacite from rutting.

There is evidence of water trapped between the seal layers and a preference is given to removing the seal layers.

The design traffic load, for a 25 year period for the site is 13 million ESA, and for a 10 year period is 4.5 million ESA.

The pavement rehabilitation strategy is presented in detail in Section 4, however the proposed pavement treatments for a 10 and 25 year life basically comprises of four options:

Option 1: Remove 100mm of old seal and Reinstate new seal – 1 year life (estimated due to low rutting life of insitu Dacite aggregate found from RLT testing = 0.25 Million ESA).

- Step 1: mill off existing seal.
- Step 2: Apply top up metal of AP20 (NZTA M4 quality that is not Dacite and has a average slope in the 1st 5 stages of the NZTA T15 RLT test of 0.55%/1M or less) to reshape and restore cross-fall of at least 3%
- Step 3: 1st coat chipseal and reinstate pavement markings
- Step 4: 2nd coat chipseal for surface waterproofness

Pros	Cons
Low cost.	The top up AP20 aggregate on top of the 70mm of Dacite over an old seal could trap water and fail in blow outs with potholes
Aims to fix the only problem at this site which is chipseal flushing	This will not prevent rutting in the insitu Dacite aggregate (RLT Test is poor) and will likely accelerate rutting due to higher tyre stresses imposed on the aggregate caused by removing 100mm of seal layers
	The AP20 would act like marbles under new seal layer causing adhesion problems with the new seal to basecourse layer.

An allowance should be made to undertake dig out repairs in soft spots and badly rutted areas prior to sealing.

Option 2: 200mm Insitu stabilisation – 1 to 5 year life

- Step 1: mill off existing seal.
- Step 2: 200 mm in-situ stabilisation with 1.5% cement and reshape to restore cross-fall of at least 3%
- Step 3: 1st coat chipseal and reinstate pavement markings
- Step 4: 2nd coat chipseal for surface waterproofness

Pros	Cons
Low cost.	Disturbing an insitu aggregate that has no rutting will result in rutting as shown from the poor RLT result.
Removes the need for an imported top up aggregate	Cracking may result from stabilisation as the ITS was high approx. 500kPa with 1.5% cement

Pros	Cons
	Inistu stabilisation often results in excess of fines at the surface which then results in the overlaying chipseal not adhering to the stones and could therefore result in further flushing and potholes.

Option 3: 320mm Granular Overlay – 25 year life (or 230mm granular overlay for a 10year life)

- Step 1: mill off 100mm existing seal.
- Step 2: 320 mm M4 granular overlay (Swaps Waotu is assessed in the NZTA T15 RLT as providing adequate performance)
- Step 3: 1st coat chipseal and reinstate pavement markings
- Step 4: 2nd coat chipseal for surface waterproofness

Pros	Cons
Obtain a 25 year life	Raising pavement height will require additional shoulder material to maintain the safe shoulder slopes
New clean aggregate for better adherence of chipseal	Takes longer to construct
Overlay has been a proven treatment in the area combined with removing old seal layers	Risk of early rutting of unbound granular overlay material (although can minimise this risk through making sure aggregate passes NZTA T15 RLT criteria and achieve a minimum compaction level on site and drying back before sealing).

Option 4: 320mm Granular Overlay – 25 year life

- Step 1: mill off 220mm which includes the existing seal, dacite and old seal layer .
- Step 2: 150 mm GAP65 aggregate overlay)
- Step 3: 170 mm M4 AP40 aggregates overlay (Swaps Waotu is assessed in the RLT as providing adequate performance)
- Step 4: 1st coat chipseal and reinstate pavement markings
- Step 5: 2nd coat chipseal for surface waterproofness

Pros	Cons
Obtain a 25 year life for 320mm overlay	Increases cost although can save costs not needing extra material for the shoulders
New clean aggregate for better adherence of chipseal	Takes longer to construct with digging out 200mm
Overlay has been a proven treatment in the area combined with removing old seal layers Removal of buried seal layers allows for free vertical drainage of aggregates Results in same pavement height and thus saves on extra shoulder material Could apply this treatment within the edgelines only	Risk of early rutting of unbound granular overlay material (although can minimise this risk through making sure aggregate passes NZTA T15 RLT criteria and achieve a minimum compaction level on site and drying back before sealing). Overall pavement depth unchanged.

All materials and construction must be in compliance with relevant NZTA specifications. The designers must be advised of any conditions observed during construction that are not consistent with the data and interpretations presented in this report.

Introduction

This report presents the results of a site investigation and pavement renewal design for a 300m length of pavement on SH1 near the Thorpe Road intersection south of Atiamuri. The project is part of the Opus Central Waikato Network Outcome on Contract on behalf of NZ Transport Agency for the 2015/2016 construction season.

The site location is defined as SH1 624 RP 6258-6530.

The reports objectives are to:

- Define the motivation for pavement renewal
- Summaries of the pavement investigation information, including
  - Test pits
  - Material testing
- Recommend suitable pavement renewal design options

1. Part 1 – Setting

Thorpe Road site is a rural State Highway road, located in the Central Waikato region.

A map showing the site location is presented in Figure 1.

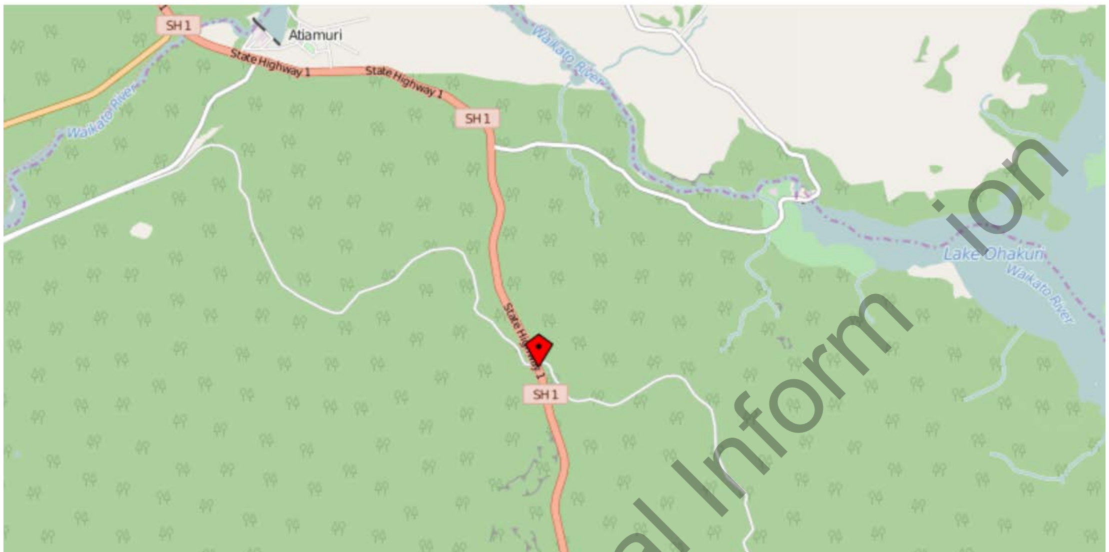


Figure 1: Location of site

An inspection of the site was carried out. Key observation from the site are as follows:

- The surface comprises of multipal chipseal layers that soften in warm weather.
- Flushing is in all four wheel tracks (Figure 2).
- In some areas the flushed chipseal has stucked to tyres and strips removed from the wheel tracks (Figure 3).
- The geometric alignment is straight (relatively horizontal) with a large radius curve.
- The posted speed limit is 100 km/hr.
- This site has had multiple seals due to short lives obtained caused by flushing. Latest sandwhich seal applied in December 2015 flushed within a month.
- Recent multiple fatality crash site combined with short seal life due to multiple soft seal layers prompted this pavement renewal design to ensure the applied chipseal surface will have sufficient texture depth to maintain skid resistance.

Figure 2a: Photo showing Thorpe Rd Site on SH1 (looking north)

Figure 2b: Photo showing Thorpe Rd Site on SH1

1.1 Renewal Drivers

The main driver for rehabilitation is the severe flushing in the wheel tracks that occurs in summer due to the high temperatures. This section has 70 to 100mm thick seal layer with a binder stone ratio of 18.2 resulting in unstable surface layers, and reducing seal life in the last 10 years. The most recent sandwich seal lasted only 1 month before flusing occurred subsequent reseals are also expected to have short lives and thus to increase the seal life to provide adequate texture and skid resistance a pavement renewal is required.

The site's pavement and surfacing history is:

Table 1 – Surfacing History

surface_date	start_m	end_m	surf_material_desc	chip_size	chip_2nd_size
15/12/2015	6259	6471	Sandwich Seal	2	4
15/12/2015	6471	6527	Two Coat Seal	2	4
10/12/2012	6259	6527	Two Coat Seal	2	4
28/01/2010	6259	6527	Racked in Seal	3	5
7/12/2006	6260	6500	Void fill seal	5	
7/12/2006	6500	6527	Void fill seal	5	
10/02/2004	6260	6527	Racked in Seal	4	6
12/02/2003	6260	6500	Racked in Seal	3	5
24/01/2001	6260	6500	Texturising Seal	5	
7/12/1994	6260	6500	Single Coat Seal	2	
7/12/1994	6260	6500	Single Coat Seal	2	
7/12/1994	6500	6527	Single Coat Seal	2	
7/12/1994	6500	6527	Single Coat Seal	2	
28/11/1994	6260	6500	Void fill seal	6	
1/09/1994	6501	6527	Two Coat Seal (1st coat)	3	5

The maintenance history from RAMM shows most of the maintenance was fixing flusing by water blasting and small areas of deformation repaired using insitu stabilisation.

Table 2 – Maintenance History

start_m	end_m	transaction_date	activity	fault	quantity (m^2)	cost
6442	6481	7/09/2000	Shoulder maintenance	Unknown fault	41	$56.17
6260	6300	15/10/2001	Shoulder maintenance	Low shoulder	40	$55.60
6500	6516	25/10/2006	In situ stabilisation	Deformation	56	$1,020.32
6283	6367	20/06/2009	Surfacing defect repairs	Flushing	84	$589.68
6283	6363	20/06/2009	Surfacing defect repairs	Flushing	80	$561.60
6412	6502	20/06/2009	Surfacing defect repairs	Flushing	90	$631.80
6420	6495	20/06/2009	Surfacing defect repairs	Flushing	75	$526.50
6447	6507	20/06/2009	Surfacing defect repairs	Flushing	60	$421.20
6330	6337	31/12/2009	Shoulder maintenance	Edge break	7	$42.00
6300	6432	10/05/2011	Waterblasting	Flushing	594	$5,821.20
6300	6305	10/05/2011	Waterblasting	Flushing	22.5	$220.50
6330	6337	10/05/2011	Waterblasting	Flushing	7.7	$75.46
6440	6465	10/05/2011	Waterblasting	Flushing	55	$539.00
6280	6328	21/09/2011	Shoulder maintenance	Edge break	48	$288.00
6290	6308	1/11/2011	In situ stabilisation	Fatigue Cracking	37.8	$876.96
6260	6280	8/03/2012	Surfacing defect repairs	2nd Coat	80	$489.60
6270	6344	6/06/2012	Waterblasting	Flushing	88.8	$870.24
6280	6332	6/06/2012	Waterblasting	Flushing	62.4	$611.52
6300	6334	6/06/2012	Waterblasting	Flushing	40.8	$399.84
6430	6508	6/06/2012	Waterblasting	Flushing	93.6	$917.28
6440	6500	6/06/2012	Waterblasting	Flushing	72	$705.60
6410	6520	7/06/2012	Waterblasting	Flushing	264	$2,587.20
6330	6350	20/12/2012	Shoulder maintenance	Edge break	20	$120.00
6301	6311	30/06/2015	Waterblasting	Flushing	10	$82.00
6391	6411	30/06/2015	Waterblasting	Flushing	34	$278.80
6461	6471	30/06/2015	Waterblasting	Flushing	17	$139.40
6273	6473	11/11/2015	Surfacing defect repairs	Bleeding	1200	$1,620.00

A summary from the net present value 2014 justification report shows the following NPV calculations. The "Do Something" and 'Full Renewal" options are compared to the "Do Minimum option", Net Present Values and Economic Indicators can be calculated for each option.

Table 3 – Economic Evaluation Calculations for different pavement strategy

Do Min PV	Do Something PV	Full Renewal PV	Preferred Option	Preferred Option Saving	EI Preferred Option
$306,543.00	$232,857.00	$216,418.00	Do Minumum	$90,053.00	1.64

Notes*

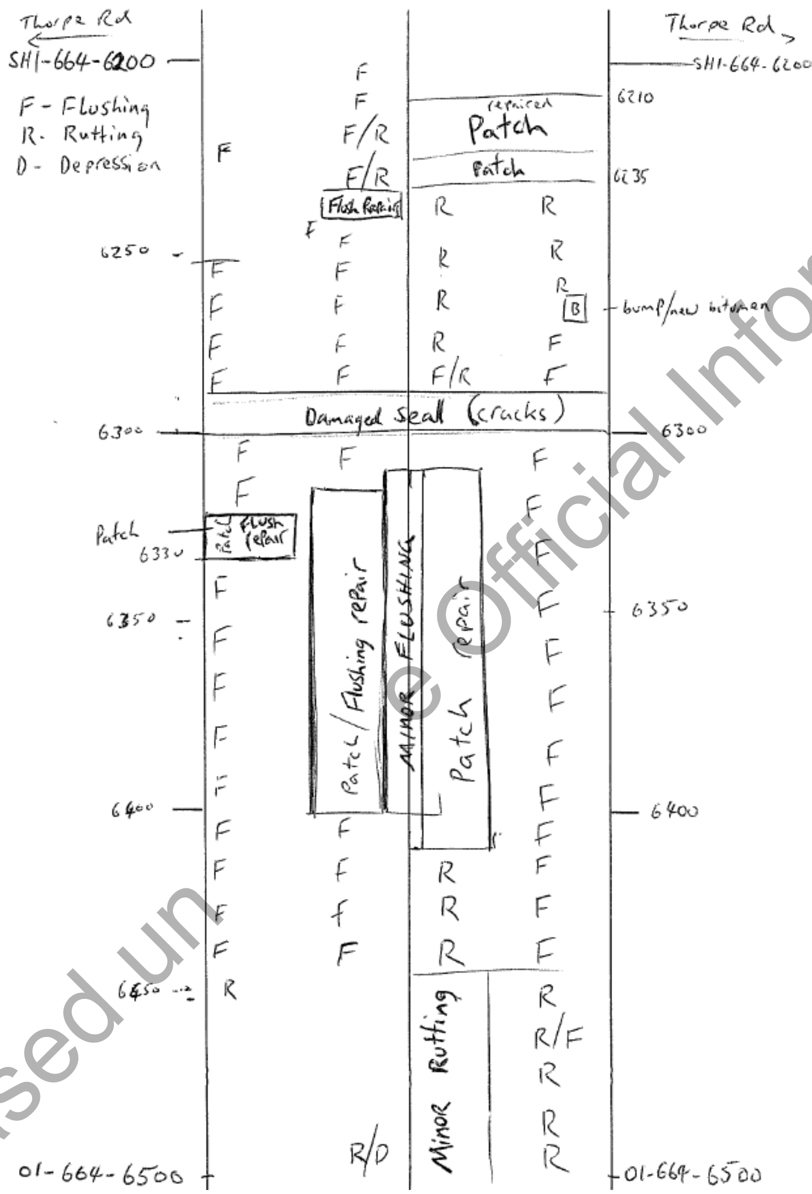
This can be seen below. Reduction of Disruption factors were not calculated for this site as AADT < 25,000

2. Part 2 – Investigations

This section summarises the investigations completed to date.

2.1 Site Survey

A walk-over on the site was carried out, defects were continuous wheel track flushing and some seal loss due to the seal sticking to the tyres.



2.2 Test pits

Two test pits were excavated at the site on 9th February 2016. Test pits logs and Scala Penetrometer results are presented below, and layer thicknesses and descriptions are summarised in Figure 6.

The tests pits in the rehabilitation section generally show:

- 70 to 100 mm flushed and soft chipseal surfacing layers
- 70 mm of AP40 basecourse aggregates (Dacite)
- 30 mm of old seal
- 90 mm of AP40 basecourse aggregates (Dacite)
- 35 to 75 mm of old seal
- 115 mm to 140 mm AP65 subbase aggregate (Dacite)
- Subgrade (Pumice).
- Total pavement thickness (includes seal layers) of 550mm with a scala measured subgrade CBR >13% (*note as the subgrade is pumice it is likely the modulus based on back calculated Falling Weight Deflectometer testing is 30 to 50 MPa*)

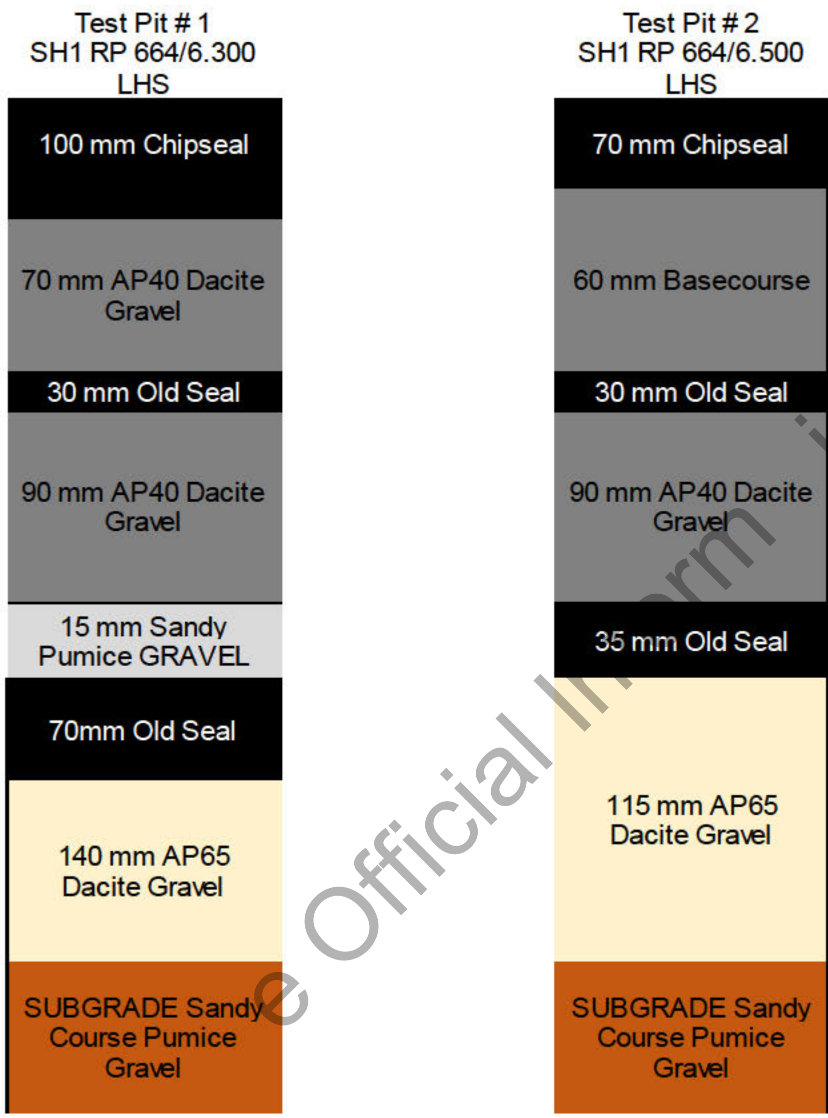


Figure 6 Test pit Summary

2.3 Stiffness

No FWD testing has been carried out, nor is in the RAMM records.

2.4 Materials Lab Testing

2.4.1 Repeated Load Triaxial Testing

Repeated Load Triaxial Testing was carried out on 11th February 2016 as per NZ Transport Agency T15 specification.

A summary of the key findings are in Table 4:

Table 4 – Summary of RLT results

RLT Test	Dry Density	Moisture Content	Resilient Modulus	Average Slope	Recommend Performance Criteria for Design
T16/352A (AP40 Dacite Gravel + 15% old seal)	2.097 t/m^3	6.6%	170 MPa	Failed in 4th stage of a 6th stage test	$N = \left(\frac{0.972}{\epsilon}\right)^{2.15} \quad if\ \mu\epsilon \leq 1855$ *(Note a poor result if used as a basecourse with a thin surface life predicted is 0.25 Million ESA before rutting failure)*

The raw RLT result when tested in dry conditions of the AP40 Dacite Gravel sampled from the road is shown in Figure 7. As can be seen this is a very poor result and rutting failure of this aggregate is highly likely if the 100mm seal layer is removed.

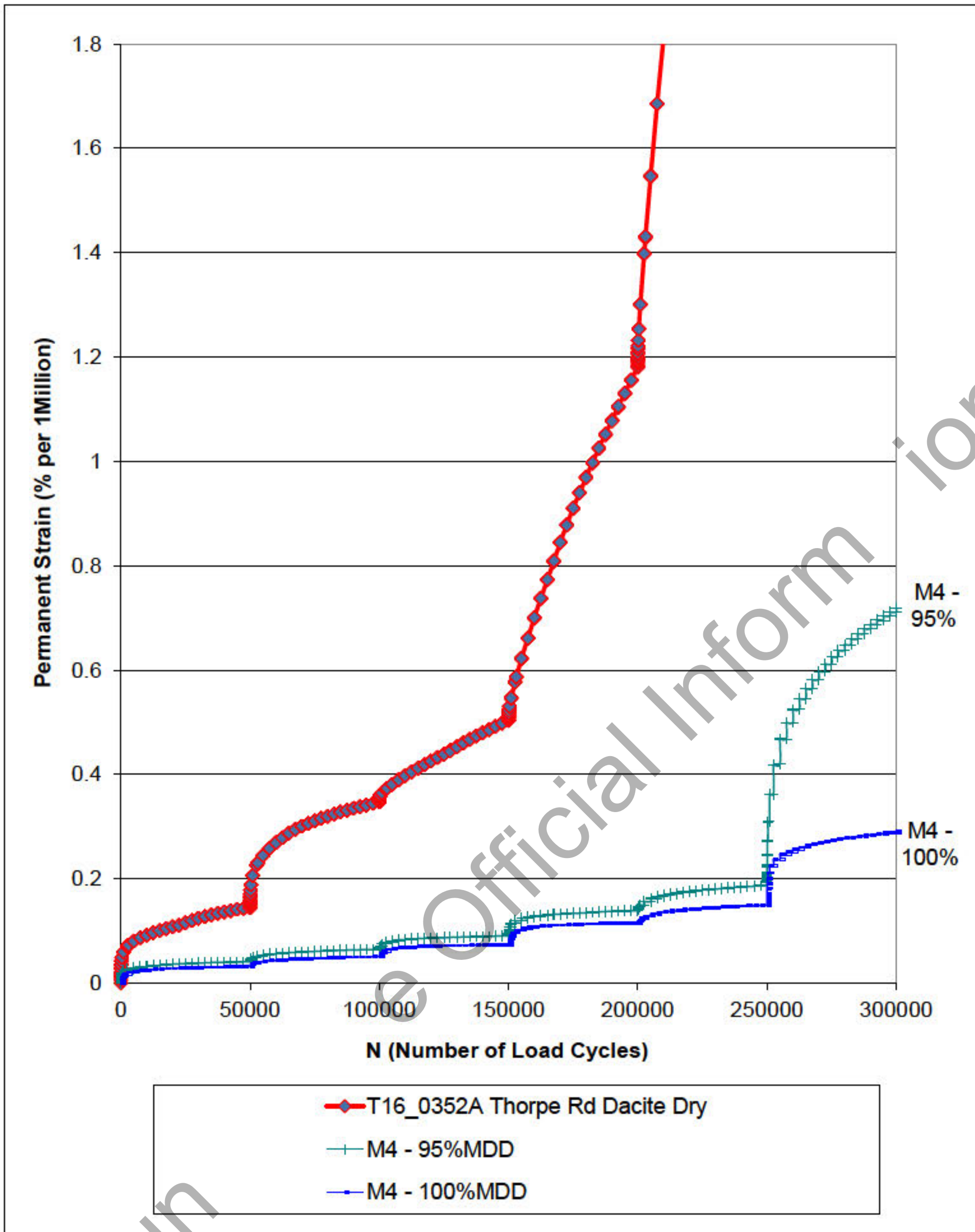


Figure 7 Raw RLT Test Result for Insitu Dacite Basecourse

2.4.2 Indirect Tensile Strength Testing

A summary of the indirect tensile strength tests findings are recorded in in Table 5 and Table 6.

Cement at 1.5%

Table 5 – Summary of ITS results for 1.5% Cement

Reference No.	Condition	Moisture Content As Compacted (%)	Moisture Content after soaking (%)	Cure time @ 40°C (hours)	Dry Density pre ITS Test (kg/m³)	Maximum Indirect Tensile Stress (kPa)
T16/0352B D1	unsoaked	7	7	72	2020	515
T16/0352B W1	soaked	7	8	72	2020	518

An ITS life multiplier of 5 times (maximum allowable) is calculated based on a 515 kPa result.

Cement at 3%

Table 6 – Summary of ITS results for 3% Cement

Reference No.	Condition	Moisture Content As Compacted (%)	Moisture Content after soaking (%)	Cure time @ 40°C (hours)	Dry Density pre ITS Test (kg/m³)	Maximum Indirect Tensile Stress (kPa)
T16/0352C D1	unsoaked	7.8	7.8	72	2095	889
T16/0352C W1	soaked	7.8	8.4	72	2062	810

An ITS life multiplier of 5 times (maximum allowable) is calculated based on a 810 kPa result.

2.5 Services

For the site extent a full survey of overhead and underground services is required to ensure that these are not hit during construction.

3. Part 3 – Options Recommendation

This section details the reasons for the pavement failure and summarises recommended treatments for further detailed design.

3.1 Basecourse Quality Assessment

The following testing, as outlined in the table below, was carried out on the basecourse.

Table 7 Summary of Basecourse Aggregate Testing

Testing	Comment
Repeated Load Triaxial (RLT)	The resconsituted aggregate failied in the fourth stage. In-situ behaviour suggests the existing aggregate if hoed or not overlaid with at least 150mm will perform poorly.
Indirect Tensile Strength (ITS)	An ITS life multiplier of 5 times the unbound life in terms of rutting is calculated based on a 515 KPa result with 1.5% cement and an ITS of 810 kPa with 3% cement. *However, designing a bound pavement on a pumice subgrade is not recommended due to the high pavement deflections on volcanic subgrades. Thus any cement stabilisation will return to unbound very quickly (with the possibility of cracking) and when unbound, the material (dacite aggregate) will fail in rutting as indicated in the RLT test.*

Overall the existing basecourse even when dry is prone to rutting, which is a typical property of Dacite aggregates. From reactive testing, cementing the aggregate does improve strength and stiffness but the strength will reduce by fatigue due to the high deflecting environment on the pumice subgrade.

3.2 Failure Mode Analysis

Thorpe Rd has failed by a surface flushing, observation and reasons are summarised in the table below: The site has little cracking and rutting as the Distress Map shows, this demonstrates the surface is more of an issue than the pavement. Although a reason for multiple seal layers could be due to flushing and smoothing any wheel track ruts that may have formed.

Table 8 Summary of Pavement Failure and Cause of Failure

Failure Mode	Photo	Cause of Failure
Flushing		Flushing as occurred for over a decade on this site, water cutting along with resurfacing has been a regular activity with the recwith old chip seal layers underneath. Flushing is attributed to construction issues. Either "stripping" of the seal during application or "fatty fines" in the basecourse preparation.
Rutting		Visually the site shows wheel track rutting possibly due to the Dacite aggregate used which is prone to rutting. The ruts could also form due to rutting within the soft multiple seal layers.

3.3 Pavement Treatment Options (Treatment Selection)

The site inspection, investigation, material testing indicates that the existing pavement distress can be attributed to a number of factors detailed in the Table below.

Additional points of interpretation and design considerations have been established from the investigation. A summary of these factors are presented in Table:

Table 8 Summary of Pavement Failure and Cause of Failure

Item	Interpretation	Consideration
Pavement Alignment and Configuration	On embankement in large open area with swale drains	There are no constraints for an overlay
Moisture conditions	Existing aggregate remains moist likely from water trapped between seal layers. Shading from the mature trees may also result in increased moisture in the pavement.	Consider removing seal layers from pavement and daylighting by removing large trees shading the road.
Material quality	Material testing using the RLT shows basecourse aggregate is prone to rutting	Basecourse strain criteria derived from RLT testing on the insitu Dacite aggregate will be used to determine overlay depth to prevent rutting failure within the design life.
Surfacing requirements	Current chipseal for the full length of the site has flushed.	At the very least the unstable seal layers need to be removed before any pavement renewal design is considered.

3.3.1 Option 1 – Remove 100mm existing Seal Layers and Reinstate new seal – 1 year life (Not recommended)

The proposed treatment at this site is to mill off existing seal layers, localised digouts in soft spots, tidy up the remaining surface irregularity by placing a 20 to 50 mm layer of M4 quality AP20. This followed by a 1st coat chip seal and then a 2nd coat chip seal.

Option 1: Remove 100mm of old seal and Reinstate new seal – 1 year life (estimated due to low rutting life of insitu Dacite aggregate found from RLT testing = 0.25 Million ESA).

- Step 1: mill off existing seal.
- Step 2: Apply top up metal of AP20 (NZTA M4 quality that is not Dacite and has a average slope in the 1st 5 stages of the NZTA T15 RLT test of 0.55%/1M or less) to reshape and restore cross-fall of at least 3%
- Step 3: 1st coat chipseal and reinstate pavement markings
- Step 4: 2nd coat chipseal for surface waterproofness

Pros	Cons
Low cost.	The top up AP20 aggregate on top of the 70mm of Dacite over an old seal could trap water and fail in blow outs with potholes
Aims to fix the only problem at this site which is chipseal flushing	This will not prevent rutting in the insitu Dacite aggregate (RLT Test is poor) and will likely accelerate rutting due to higher tyre stresses imposed on the aggregate caused by removing 100mm of seal layers
	The AP20 would act like marbles under new seal layer causing adhesion problems with the new seal to basecourse layer.

An allowance should be made to undertake dig out repairs in soft spots and badly rutted areas prior to sealing.

3.3.2 Option 2 - 200mm Insitu stabilisation – 1 to 5 year life (Not recommended)

Insitu Stabilisation. This option involves milling off the 100mm existing seal layers and cut this to waste. Leaving the seal layers in place is not considered a viable option as this will result in the stabilised mix consisting of 50% seal and 50% aggregate which will become unstable. After milling of the chipseal insitu stabilise to a depth of 200 mm with 1.5% cement. Then apply a 2 coat chip seal. The design relies on the basecourse strain criterion with a multiplier of life due to tensile strength gain from the ITS.

Option 2: 200mm Insitu stabilisation – 1 to 5 year life

- Step 1: mill off existing seal.
- Step 2: 200 mm in-situ stabilisation with 1.5% cement and reshape to restore cross-fall of at least 3%
- Step 3: 1st coat chipseal and reinstate pavement markings
- Step 4: 2nd coat chipseal for surface waterproofness

Pros	Cons
Low cost.	Disturbing an insitu aggregate that has no rutting will result in rutting as shown from the poor RLT result.
Removes the need for an imported top up aggregate	Cracking may result from stabilisation as the ITS was high approx. 500kPa with 1.5% cement
	Inistu stabilisation often results in excess of fines at the surface which then results in the overlaying chipseal not adhering to the stones and could therefore result in further flushing and potholes.

This design relies on taking the existing seal layers off. However, RLT testing on the insitu aggregate gave a life of 0.25 Million ESA (Table 4 RLT results) and multiplying the life by 5 times due to increased tensile strength from cement stabilisation results in a life of 1.25 Million ESA which for this site is 2 years.

3.3.3 Option 3 – Remove 100mm seal layer and then 320 mm Granular Overlay – 25 year life (Recommended Option) or 230mm Granular Overlay 10 year life

Mill and overlay. The overlaid depth is determined for either a 10 year and 25year life, this option involves milling off the existing seal layers, then ??? mm overlay of imported M4 AP40 aggregate. The aggregate would need to have an average slope for the 6 stages of less than 0.55% per million, through proof testing in the RLT. Due to the poor rut resistance of the underlying Dacite aggregate as found in the RLT test the overlay depth should also meet the AUSTROADS minimum basecourse material as per their pavement thickness design chart (170mm as per Figure 8.4 in the 2004 Austroads Pavement Design Guide). The expected design life is 25 years. A 2 coat

1st coat chip seal would follow. The design relies on the basecourse strain criterion, and suitable basecourse preparation.

Option 3: 320mm Granular Overlay – 25 year life (or 230mm granular overlay for a 10year life)

- Step 1: mill off 100mm existing seal.
- Step 2: 320 mm M4 granular overlay (Swaps Waotu is assessed in the RLT as providing adequate performance)
- Step 3: 1st coat chipseal and reinstate pavement markings
- Step 4: 2nd coat chipseal for surface waterproofness

Pros	Cons
Obtain a 25 year life	Raising pavement height will require additional shoulder material to maintain the safe shoulder slopes
New clean aggregate for better adherence of chipseal	Takes longer to construct
Overlay has been a proven treatment in the area combined with removing old seal layers	Risk of early rutting of unbound granular overlay material (although can minimise this risk through making sure aggregate passes NZTA T15 RLT criteria and achieve a minimum compaction level on site and drying back before sealing).

3.3.1 Option 4 – Remove 220mm (to remove surface and buried seal layers) then overlay with 150mm GAP65 aggregates and 170mm M4 AP40 aggregates.

Mill or dig out 220mm and overlay. The overlaid depth is determined for either a 10 year and 25year life, this option involves milling off the existing seal layers plus the 70mm Dacite layer and then a 30mm old seal, then 150mm overlay of imported GAP65 aggregate and 320 mm overlay of imported M4 AP40 aggregate. The aggregate would need to have an average slope for the 6 stages of less than 0.55% per million, through proof testing in the RLT. Due to the poor rut resistance of the underlying Dacite aggregate as found in the RLT test the overlay depth should also meet the AUSTROADS minimum basecourse material as per their pavement thickness design chart (170mm as per Figure 8.4 in the 2004 Austroads Pavement Design Guide). The expected design life is 25 years. A 2 coat 1st coat chip seal would follow. The design relies on the basecourse strain criterion, and suitable basecourse preparation.

This options all seal layers currently within the pavement to allow for free vertical drainage of the overlying aggregate.

Option 4: 320mm Granular Overlay – 25 year life

- Step 1: mill off 220mm which includes the existing seal, dacite and old seal layer .
- Step 2: 150 mm GAP65 aggregate overlay)
- Step 3: 170 mm M4 AP40 aggregates overlay (Swaps Waotu is assessed in the RLT as providing adequate performance)
- Step 4: 1st coat chipseal and reinstate pavement markings
- Step 5: 2nd coat chipseal for surface waterproofness

Pros	Cons
Obtain a 25 year life	Increases cost although can save costs not needing extra material for the shoulders
New clean aggregate for better adherence of chipseal	Takes longer to construct with digging out 200mm
Overlay has been a proven treatment in the area combined with removing old seal layers	Risk of early rutting of unbound granular overlay material (although can minimise this risk through making sure aggregate passes NZTA T15 RLT criteria and achieve a minimum compaction level on site and drying back before sealing).
Removal of buried seal layers allows for free vertical drainage of aggregates	
Results in same pavement height and thus saves on extra shoulder material	Overall pavement depth unchanged.
Could apply this treatment within the edgelines only	

3.4 Safety Assessment Form

This site shall be assessed to determine if any safety improvements are needed.

3.5 Options Economic Evaluation

3.5.1 Capital Costs

Table 9 Summary of Capital Costs for Each Option

Option	Capital Cost
Option 1 – Remove existing seal Layer	$216,418
Option 2 – 200mm In-situ Stabilisation	$232,857
Option 3 – Overlay 320mm M4 AP40	$306,461

3.5.2 NPV Check

[Update the Annual Plan NPV economic analysis with actual project costs and examine impact on NPV and EI. Acceptable treatment options must still pass the economic gatekeeping function. Present respective NPV's and EI's for the proposed options to the principal for consultation. The outcome may require adjustment to the project scope if economic gateways are not met. (Ref SM018 Annual Plan Pavement rehabilitation justification requirements). Discuss outcome with Asset manager / Engineer]

Table 10 Summary of Economic Analysis

Option	Capital Cost	NPV	EI
Option 1 – Remove existing seal Layer	$216,418	$73,604	-1.97
Option 2 – 200mm In-situ Stabilisation	$232,857	$90,053	1.64
Option 3 – Overlay 320mm M4 AP40	$306,461	$16,449	0.18

3.5.3 Options Assessment Summary

[Summarise the outcome of the concept development meeting with principal. Include date, time, location, those present and agreement reached].

4. Part 4 – Detailed Design

This section describes the analysis based on the methodology related to the accepted option from Part 3.

4.1 Design Basis

Pavement design analysis have been undertaken using the procedures and performance criteria as detailed in the AUSTROADS (2012) Guide to Structural Design of Road Pavements, the accompany TNZ (2007) Supplement. The CIRCLY v5.0 software has been used for the pavement modelling.

Resilient modulus and performance criteria for in situ granular basecourse has been derived as per NZ Transport Agency T15 Specification Repeated Triaxial Testing for Pavement Materials.

4.2 Traffic

The total Equivalent Standard Axles (ESA) calculated for a 10 and 25 year period is 4.5×10^6 and 13.0×10^6 respectively.

This ESA is determined using traffic data *(supplied by source)* and based on an arithmetic growth.

- AADT 5812 *(Source: RAMM 2014)*
- Direction Factor 0.5
- Growth Rate 2% *(Source: Estimated)*
- % HCV 23% *(Source: RAMM 2014)*
- *ESA per HCV* *67 Drury WIM*
- Design Life 25 years *(2012 Austroads Pavement Design Manual)*

The traffic count estimate information was obtained from RAMM for the 2014 count.

It is noted as per the NZ Supplement to the Document, Pavement Design – A Guide to the Structural Design of Road Pavements (Austroads, 2004) 2007, the desired project reliability if between 90-97.5% for Rural Strategic road. This road type is defined as being an arterial and collector road connecting main centres of population greater than 2,500 vehicles per day.

4.3 Pavement Analysis

4.3.1 Empirical Analysis

The cover to the subgrade is known to be 550 mm over a pumice subgrade with the lowest scala CBR of 13% measured.

In addition, as no FWD was available, a back-calculation on the subgrade could not be estimated.

At 550 mm, a CBR13 is assumed.

Hence, Austroads Figure 8.4 suggests nil cover. In fact with 550mm of aggregate cover the subgrade CBR can be as low as 4% but still able to meet the 25 year design life.

In addition, Austroad's Figure 8.4 recommends a minimum 170 mm of base material as the existing top aggregate.

Table 11 Summary of Capital Costs for Each Option

Test Pit No.	Inferred CBR	Existing Depth (mm)	10 year Life: Fig 8.4 Required Depth (mm)	25 year Life: Fig 8.4 Required Depth (mm)
1	13%	550 mm	Nil	Nil
2	13%	550 mm	nil	Nil
Assummed based on pumice subgrade modulus of 40MPa	4%	550 mm	Nil	Nil

4.3.2 Mechanistic Analysis – Treatment Options

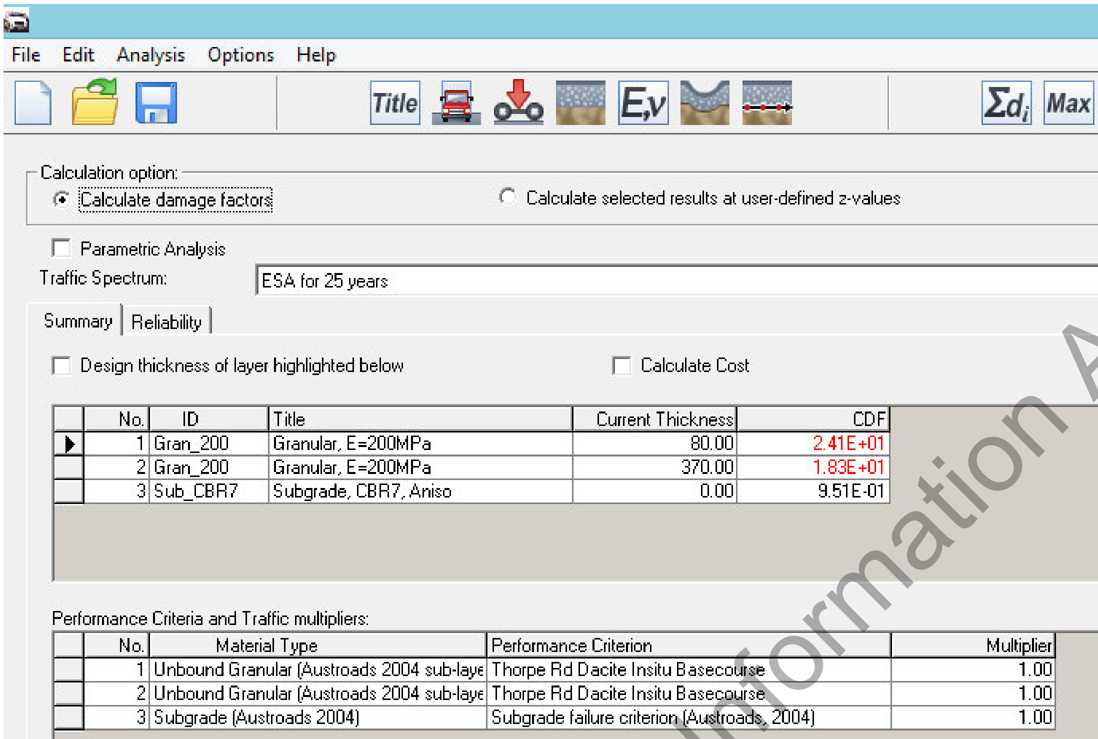
4.3.2.1 Option 1 – Remove seal layers and reinstate new seal

Option 1 is to remove the seal layers and apply a new seal coat directly onto the insitu basecourse and is described in detail in Section 3.3.1. This option will likely have a short life less than 1 year for two reasons the first is the poor rut resistance of the insitu aggregate found from RLT testing and the second reason is the trapped water in the 70mm of insitu Dacite on top of old seal layers. Nevertheless, CIRCLY is used to analyse this pavement option using the strain criteria for the insitu Dacite derived from RLT testing combined with the Austroads Subgrade Strain Criterion.

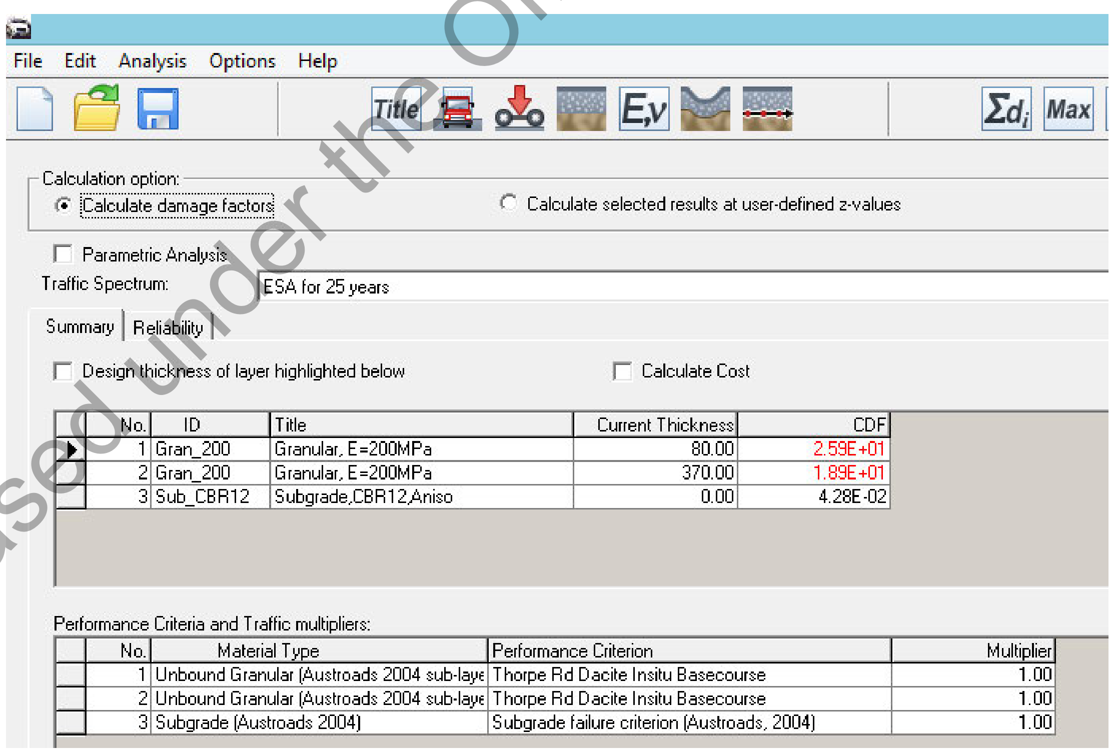
Based on the test pits, a cover to subgrade of 550 mm, although when the 100mm seal layer is removed the cover is 450mm. The lowest scala subgrade CBR measured was 13% which gives a design modulus of 130MPa, however, the design is checked using a modulus of 70MPa (or CBR 7%) due to the high deflecting nature of pumice subgrades. The design cross-section is shown below:

Thickness	Description
450 mm	**Basecourse** Insitu Dacite RLT tested E = 200 MPa Strain Criteria (*check 80mm depth*) $N = \left(\frac{0.972}{\epsilon}\right)^{2.15}$ $if\ \mu\epsilon \leq 1855$ Austroads Auto Sub-layering
infinite	**Subgrade** CBR 7%, E= 70 MPa

CIRCLY results are shown below, where it can be seen the inistu Dacite aggregate with a cumulative damage ratio (design life divided by actual life) of 24 shows that rutting failure will occur in approximately 1 year (ie. 1/24th of 25 years).



Repeating the analysis with a subgrade CBR of 12% closer to the scala measured CBR of 13% results in the same short 1 year li e of the insitu Dacite aggregate as shown below with a CDF of 25.9.



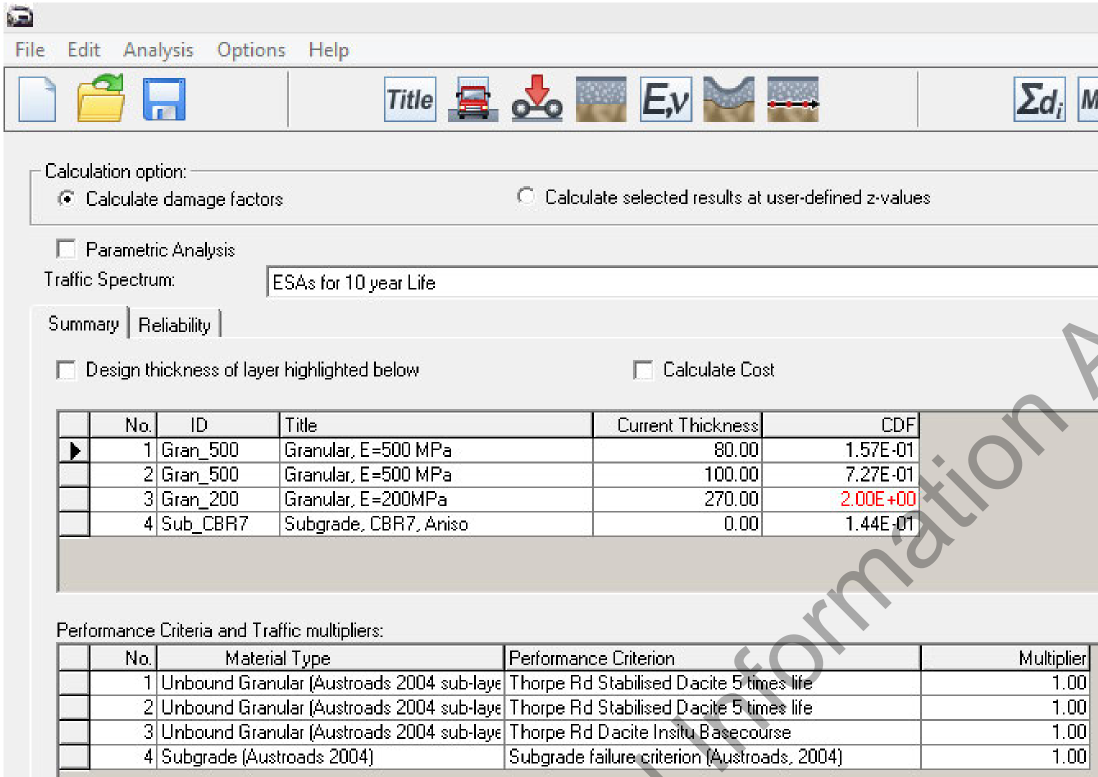
4.3.2.2 Option 2 – 200mm Insitu Stabilisation

- Step 1: mill off existing seal.
- Step 2: 200 mm in-situ stabilisation with 1.5% cement and reshape to restore cross-fall of at least 3%
- Step 3: 1st coat chipseal and reinstate pavement markings
- Step 4: 2nd coat chipseal for surface waterproofness

The design cross-section for this option is detailed below:

Thickness	Description
180 mm (effective stabilisation depth for hoe depth of 200mm)	**Insitu Stabilised Basecourse 1.5%cement** Insitu Dacite RLT tested with 5 times life for 1.5% cement (ITS 500 kPa) E = 500 MPa (as per good quality aggregate) Strain Criteria (*check 80mm depth*) $N = \left(\frac{0.972 * 5^{1/2.15}}{\epsilon}\right)^{2.15} \quad if\ \mu\epsilon \leq 1855$
270 mm	**Basecourse** Insitu Dacite RLT tested E = 200 MPa $N = \left(\frac{0.972}{\epsilon}\right)^{2.15} \quad if\ \mu\epsilon \leq 1855$ Austroads Auto Sub-layering
infinite	**Subgrade** CBR 7%, E= 70 MPa

Results of this CIRCLY analysis for a 10 and a 25 year life are detailed below. The analysis shows that the rutting life is 5 years based on the CDF of 2 in the underlying Dacite for a 10 year life analysis. An additional check on cracking is shown that the tensiles stress at the base of the aggregate is 815kPa while the tensile strength ITS is 500kPa thus the stabilised material will break (tensile stress from wheel load is greater than strength) and cracking will occur. In summary, the life is predicted to be 5 years for this option in terms of rutting and 1 year in terms of cracking.



File Edit Analysis Options Help

Calculation option:
Calculate damage factors
Calculate selected results at user-defined z-values

Parametric Analysis

Traffic Spectrum: ESAs for 10 year Life

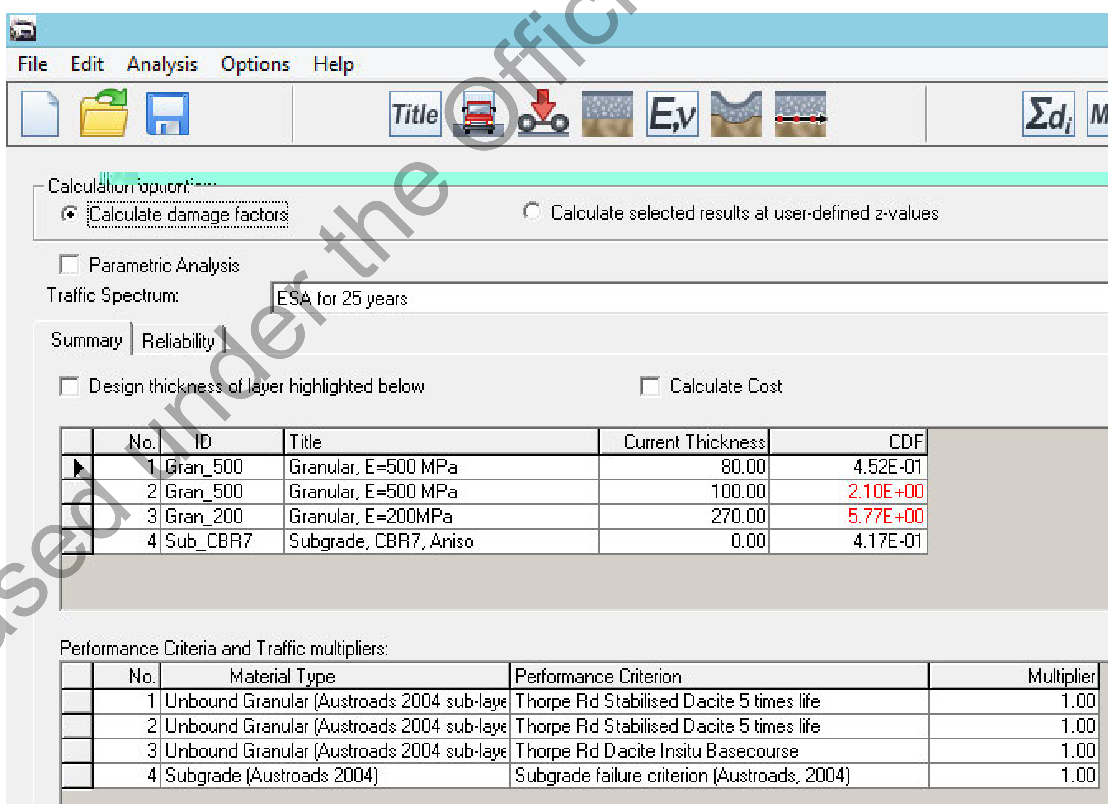
Summary | Reliability

Design thickness of layer highlighted below
Calculate Cost

No.	ID	Title	Current Thickness	CDF
1	Gran_500	Granular, E=500 MPa	80.00	1.57E-01
2	Gran_500	Granular, E=500 MPa	100.00	7.27E-01
3	Gran_200	Granular, E=200MPa	270.00	2.00E+00
4	Sub_CBR7	Subgrade, CBR7, Aniso	0.00	1.44E-01

Performance Criteria and Traffic multipliers:

No.	Material Type	Performance Criterion	Multiplier
1	Unbound Granular (Austroads 2004 sub-laye	Thorpe Rd Stabilised Dacite 5 times life	1.00
2	Unbound Granular (Austroads 2004 sub-laye	Thorpe Rd Stabilised Dacite 5 times life	1.00
3	Unbound Granular (Austroads 2004 sub-laye	Thorpe Rd Dacite Insitu Basecourse	1.00
4	Subgrade (Austroads 2004)	Subgrade failure criterion (Austroads, 2004)	1.00



File Edit Analysis Options Help

Calculation option:
Calculate damage factors
Calculate selected results at user-defined z-values

Parametric Analysis

Traffic Spectrum: ESA for 25 years

Summary | Reliability

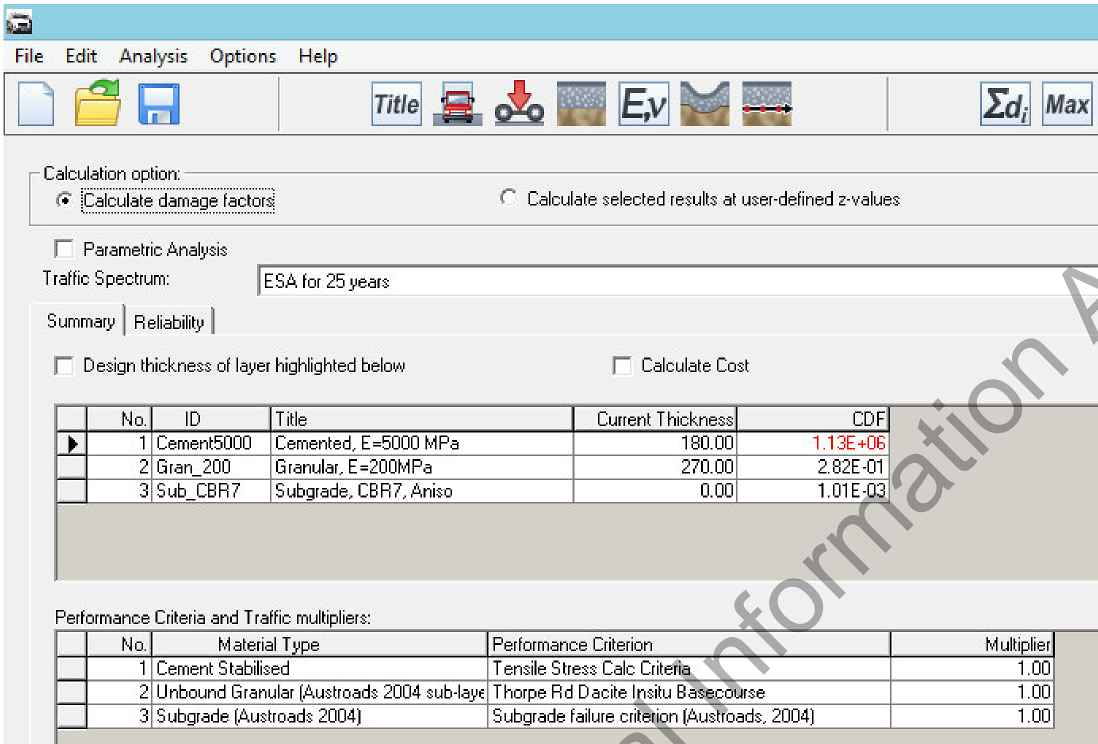
Design thickness of layer highlighted below
Calculate Cost

No.	ID	Title	Current Thickness	CDF
1	Gran_500	Granular, E=500 MPa	80.00	4.52E-01
2	Gran_500	Granular, E=500 MPa	100.00	2.10E+00
3	Gran_200	Granular, E=200MPa	270.00	5.77E+00
4	Sub_CBR7	Subgrade, CBR7, Aniso	0.00	4.17E-01

Performance Criteria and Traffic multipliers:

No.	Material Type	Performance Criterion	Multiplier
1	Unbound Granular (Austroads 2004 sub-laye	Thorpe Rd Stabilised Dacite 5 times life	1.00
2	Unbound Granular (Austroads 2004 sub-laye	Thorpe Rd Stabilised Dacite 5 times life	1.00
3	Unbound Granular (Austroads 2004 sub-laye	Thorpe Rd Dacite Insitu Basecourse	1.00
4	Subgrade (Austroads 2004)	Subgrade failure criterion (Austroads, 2004)	1.00

Tensile Stress Check for cracking



No.	ID	Title	Current Thickness	CDF
1	Cement5000	Cemented, E=5000 MPa	180.00	1.13E+06
2	Gran_200	Granular, E=200MPa	270.00	2.82E-01
3	Sub_CBR7	Subgrade, CBR7, Aniso	0.00	1.01E-03

No.	Material Type	Performance Criterion	Multiplier
1	Cement Stabilised	Tensile Stress Calc Criteria	1.00
2	Unbound Granular (Austroads 2004 sub-laye	Thorpe Rd Dacite Insitu Basecourse	1.00
3	Subgrade (Austroads 2004)	Subgrade failure criterion (Austroads, 2004)	1.00

Thorpe Road Pavement Renewal Central Waikato NOC

Cemented, E=5000 MPa
Maximum damage values for each vehicle type

Vehicle Type	Damage Factor	Critical Tensile Stress (MPa)
------------	-------------	---------------
ESA750-Full	.11278E+07	-0.81569E+00

Maximum of total damage= 1127803.

4.3.2.3 Option 3 – Remove 100mm seal layer and then 320mm M4 AP40 Granular Overlay

Option 3: 320mm Granular Overlay – 25 year life (230mm for 10 year life)

- Step 1: mill off 100mm existing seal.
- Step 2: 320 mm M4 granular overlay for a 25 year life or 230mm for a 10 year life
- Step 3: 1st coat chipseal and reinstate pavement markings
- Step 4: 2nd coat chipseal for surface waterproofness

The design cross-section for this option is detailed below:

Thickness	Description
230 mm *(10 year life)* 320 mm *(25 year life)*	**Imported new M4 AP40 Basecourse (Swaps Waotu)** Data from RLT test T15-1836A E = 400 MPa Strain Criteria (*check 80mm depth*) $N = \left(\frac{1.253}{\epsilon}\right)^{2.29}$
450 mm	**Basecourse** Insitu Dacite RLT tested E = 200 MPa $N = \left(\frac{0.972}{\epsilon}\right)^{2.15} \; if \; \mu\epsilon \leq 1855$ Austroads Auto Sub-layering
infinite	**Subgrade** CBR 7%, E= 70 MPa

Results of this CIRCLY analysis for a 10 and a 25 year life are detailed below. The analysis shows that 230mm is needed for a 10 year life before the underlying Dacite aggregate ruts based on a CDF of 1. A 25 year life requires 320mm to ensure the underlying Dacite and pavement will last for 25 years. It should be noted that over a 25 year life the imported NZTA M4 AP40 aggregate from Waotu quarry will have rutted (CDF around 1.2).

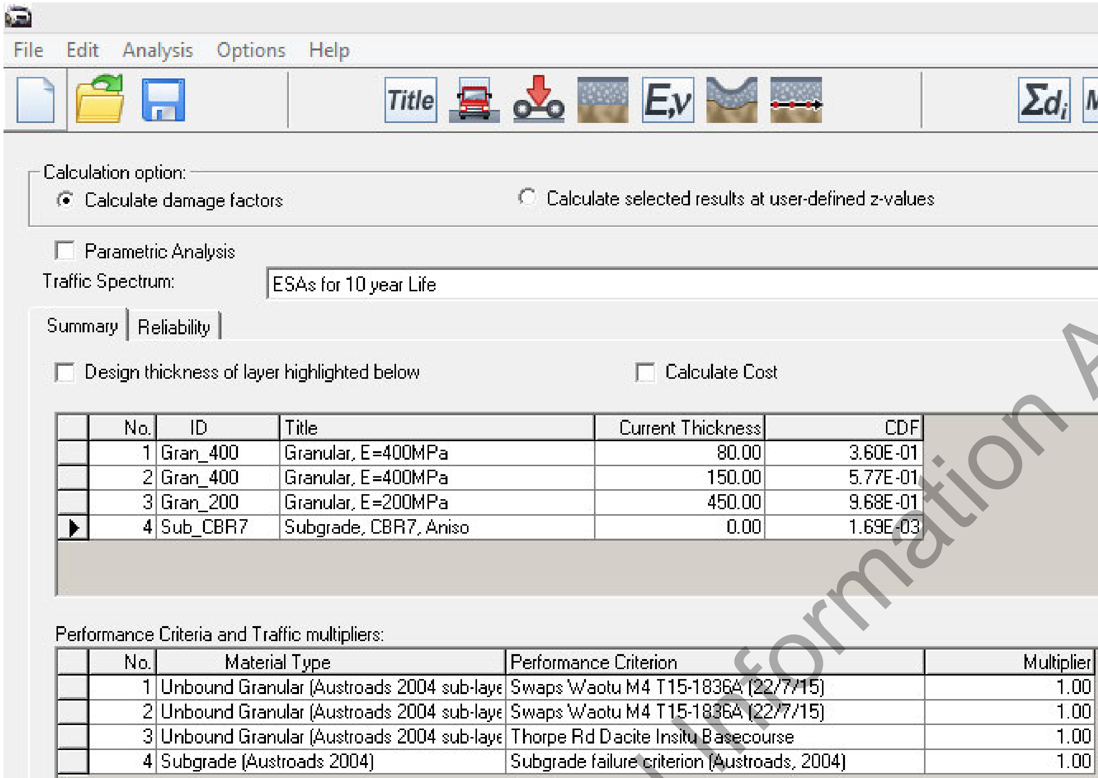


Figure – CIRCLY analysis 10 year life

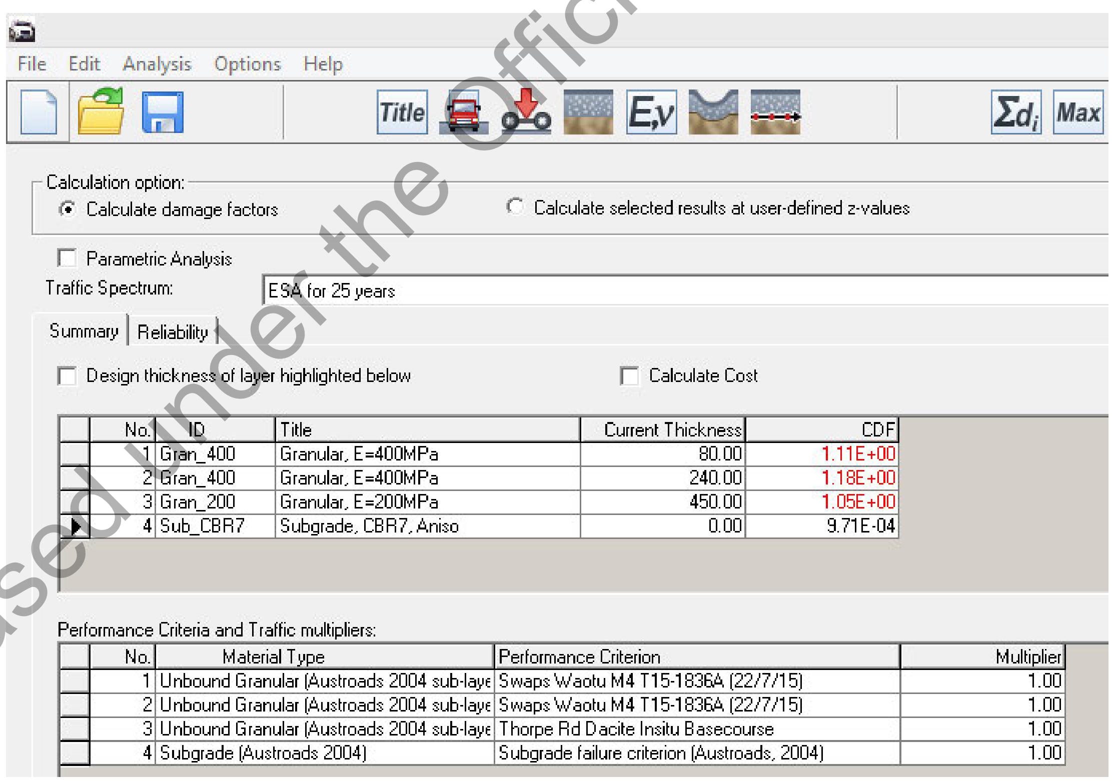


Figure – CIRCLY analysis 25 year life

Option 4.3.2.4: 320mm Granular Overlay – 25 year life

- Step 1: mill off 220mm which includes the existing seal, dacite and old seal layer .
- Step 2: 150 mm GAP65 aggregate overlay)
- Step 3: 170 mm M4 AP40 aggregates overlay (Swaps Waotu is assessed in the RLT as providing adequate performance)
- Step 4: 1st coat chipseal and reinstate pavement markings
- Step 5: 2nd coat chipseal for surface waterproofness

The design cross-section for this option is detailed below:

Thickness	Description
230 mm *(10 year life)* 320 mm *(25 year life)*	**Imported new M4 AP40 Basecourse (Swaps Waotu)** Data from RLT test T15-1836A E = 400 MPa Strain Criteria *(check 80mm depth)* $N = \left(\frac{1.253}{\epsilon}\right)^{2.29}$
350 mm	**Basecourse** Insitu Dacite RLT tested E = 200 MPa $N = \left(\frac{0.972}{\epsilon}\right)^{2.15}$ *if* $\mu\epsilon \leq 1855$ Austroads Auto Sub-layering
infinite	**Subgrade** CBR 7%, E= 70 MPa

Results of this CIRCLY analysis for a 10 and a 25 year life are detailed below. The analysis shows that 230mm is needed for a 10 year life before the underlying Dacite aggregate ruts based on a CDF of 1. A 25 year life requires 320mm to ensure the underlying Dacite and pavement will last for 25 years. It should be noted that over a 25 year life the imported NZTA M4 AP40 aggregate from Waotu quarry will have rutted (CDF around 1.2).

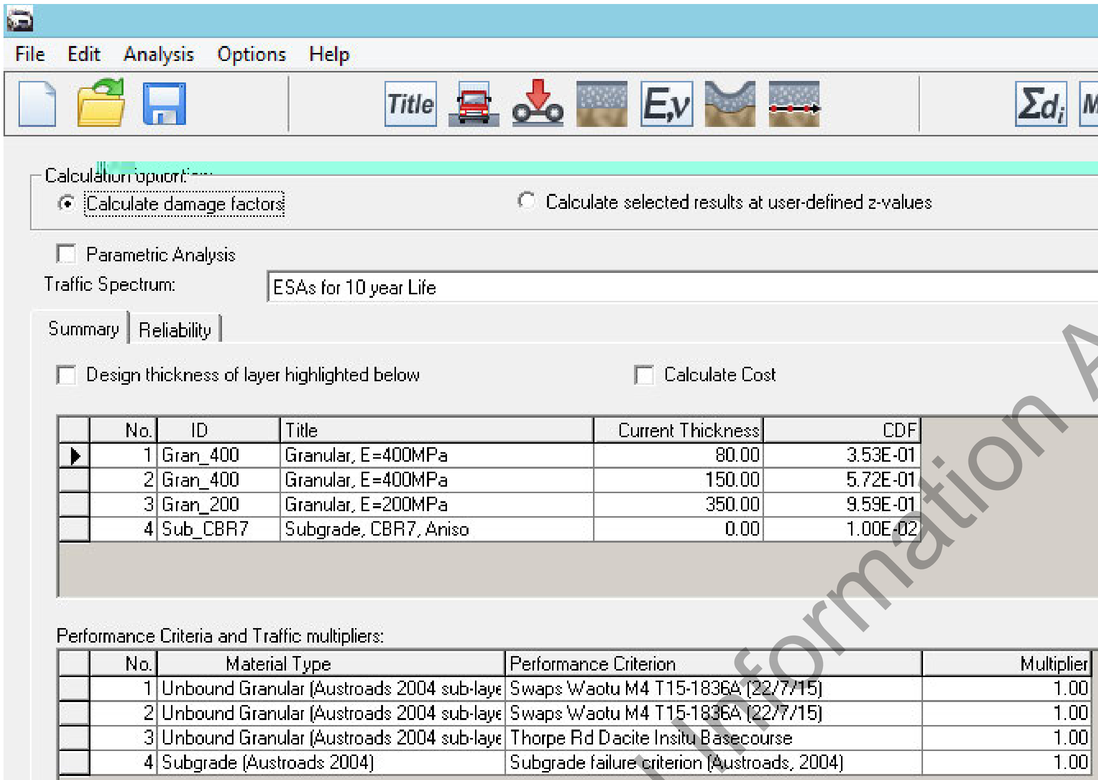


Figure – CIRCLY analysis for 10 year life

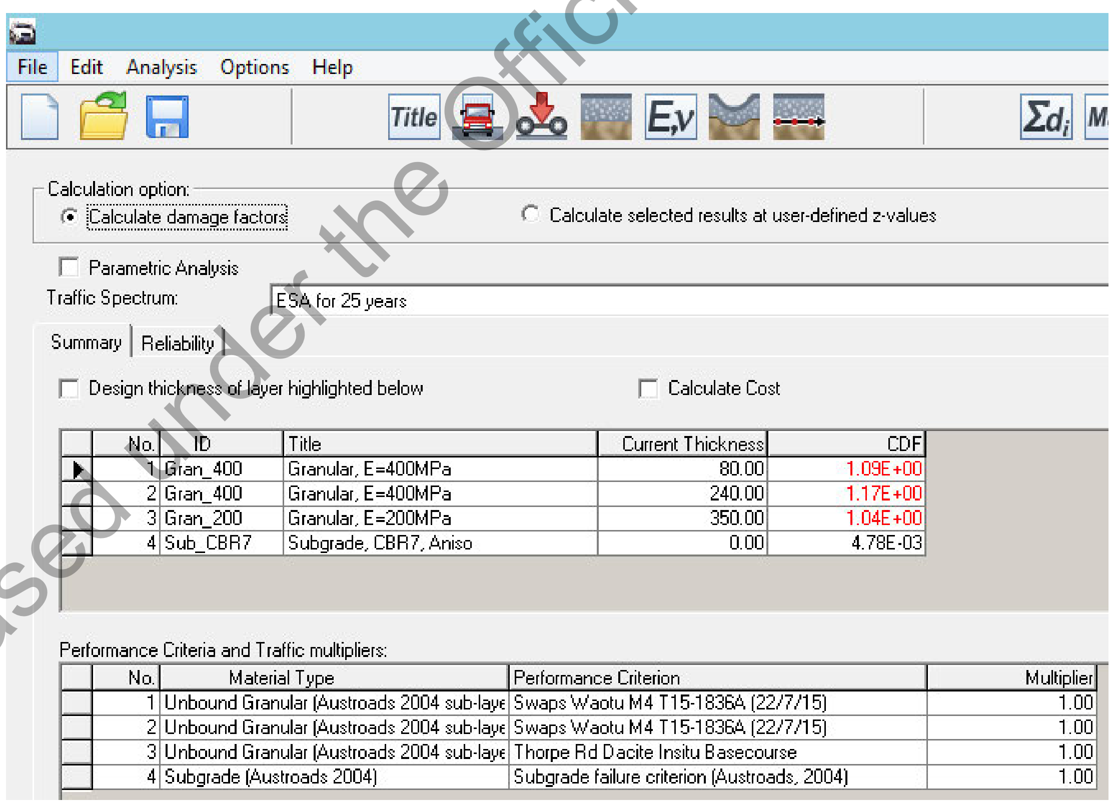


Figure – CIRCLY analysis for 25 year life

4.3.3 Ancillary Pavement Works.

For construction, pavement needs an outward cross slope of 3.0% to ensure the overlying seal can drain out to the shoulders of the road. Reshaping in areas may be needed.

A deep subsoil drain is not needed, where pavement cross-section allows water to daylight.

4.4 Geometrics

4.4.1 Design Standards

The standards used as the basis of the geometric design for this project are:

- 2005 NZTA Draft State Highway Geometric Design Manual (SHGDM)
- 2009 Austroads Guides to Road Design Part 3: Geometrics (AGRD03-10)]

4.4.2 Speed Environment

This site is located on an open and undulating section of SH 1 between Tokoroa and Taupo. The site has an easy right hand curve with no speed restriction located just south of the crossroad intersection with Thorpe Road. The speed environment for this site is 100km/h.

4.4.3 Typical Section

The design cross section used is two 3.5m lanes with a minimum of 1.5m sealed shoulders both sides. The sealed shoulders widen both sides at Thorpe Road intersection to follow the existing edge of seal. Outside of the shoulders a 5:1 feather edge leads to 1:1 fill slops to existing ground.

4.4.4 Horizontal Alignment Design

The horizontal alignment consists of two straights joined with a compound curve of approximately 1:2:1 ratio (spiral to curve to spiral). See table below for details.

Tabulate the summary of Horizontal elements:

Curve No.	**1**
Extents	RP 664 / 6.308 – 664 / 6.459
Radius	575m
Spiral Length	38m Spirals
Existing Super Elevation (SE)	+5.0% Inc, -5.5% Dec
Theoretical SE	5.7%
Adopted SE	5.7%
Design Speed	100km/h

4.4.5 Super-elevation

The design superelevation corrects the existing which has flattened on the high side of the curve. The run-in / run-out rate of change for the superelevation has been designd at 2.0% change over 1 second of travel to promote a comfortable transition in and out of the curve.

4.4.6 Sight Lines

There are no sight restrictions through this site.

4.4.7 Curve Advisory

There are no existing or proposed curve advisories at this site.

4.4.8 Vertical Alignment Design

The design vertical alignment follows the existing with minoe smoothing.

4.4.8.1 Sight Distance Criteria

The existing unrestricted site is unchanged.

4.4.9 Intersections

The existing crossroad intersection next to this site is unchanged.

4.4.10 Widening

There is no requirement for additional widening at this site.

4.4.11 Safety Improvements

- Document agreed safety improvements from the NZTA Safety Engineer to be funded from Minor Safety funding. Reference Safety Assessment Form.

4.4.12 Safety Audit

As there are no significant geometric improvements in this project, a safety audit is not required.

4.4.13 Additional Surfacing Requirement

Additional seal 0.5m wide has been added to the high side of the curve to reduce the amount of water getting into the pavement through the unsealed feather edge.

4.5 Drainage

This pavement is well drained but consideration has be given to remove old seal layers that trap water and prevent vertical downwards drainage of the granular layers.

List of Appendices

Downer

Appendix A: Test Pits and Scala's

Appendix B: Material Testing