Enhancing Pavement Design Life

Back to Basics

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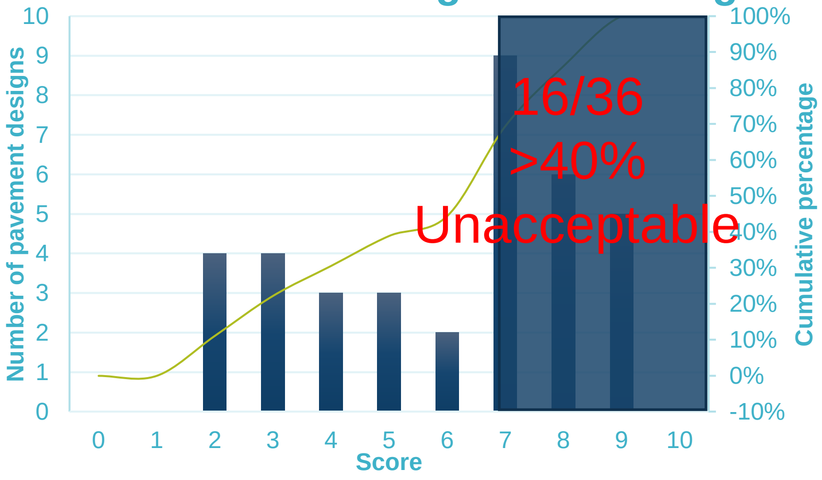
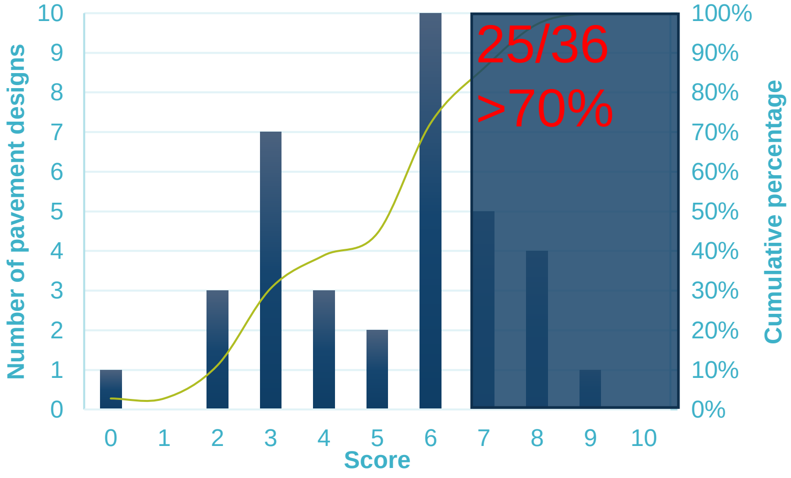
Life of pavements….

Analysis of NOC pavement designs across NZ

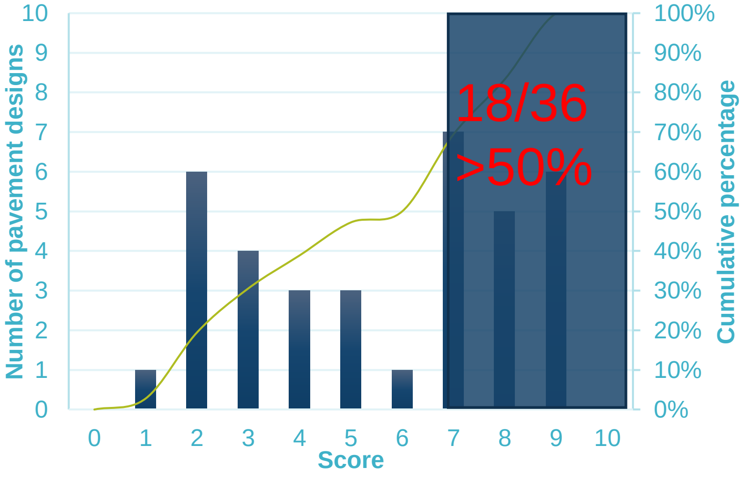
Document Editing & Formatting



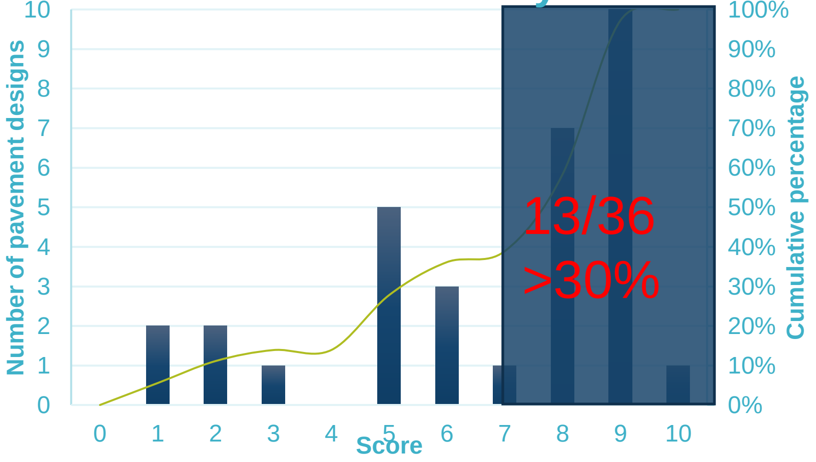
Document Detail



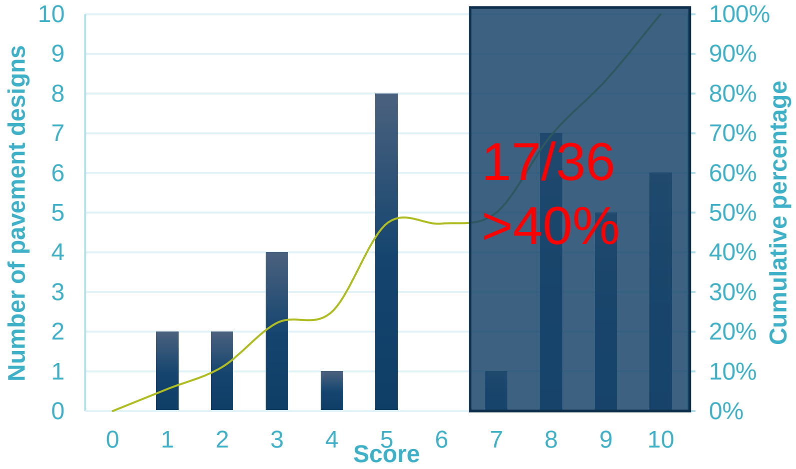
Austroads Best practice



Failure Mode Analysis



Pavement Model



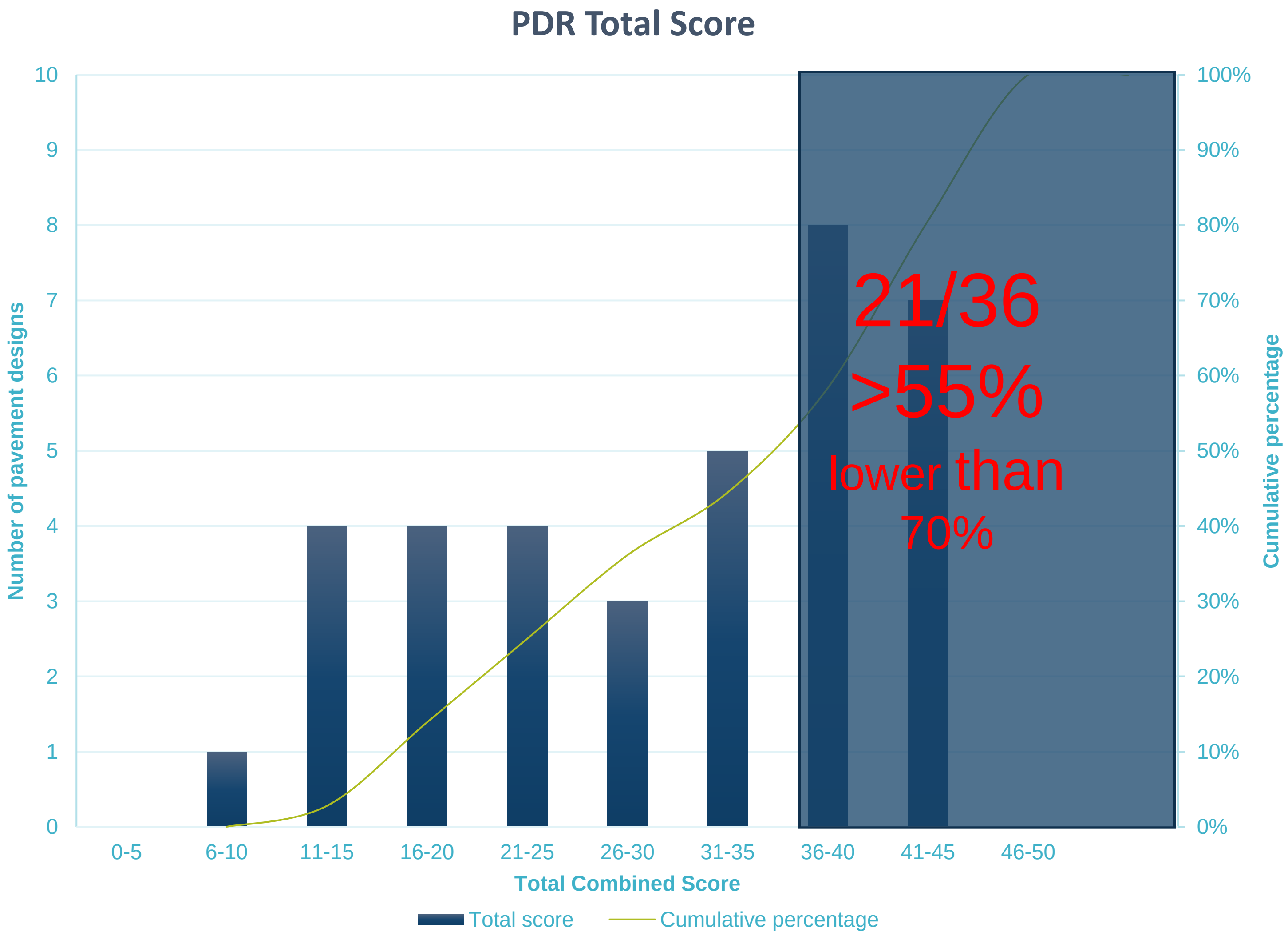
Study Representation

- Small sample size (36 PDRs)
- Most NOCs but all NOC contractors.
- Most Consultants
- Unbound, FBS, Cement and SAC

Reviews

- 36 x PDRs reviewed by Reviewer
- 10 x PDR reviewed by Moderator
- 5 x PDRs compared by 3 Principle Pavement Engineers

Analysis of NOC pavement designs across NZ



Significant portion of the PDRs have *not* carried out in accordance with NZ / Austroads good practice.

Pavement Life

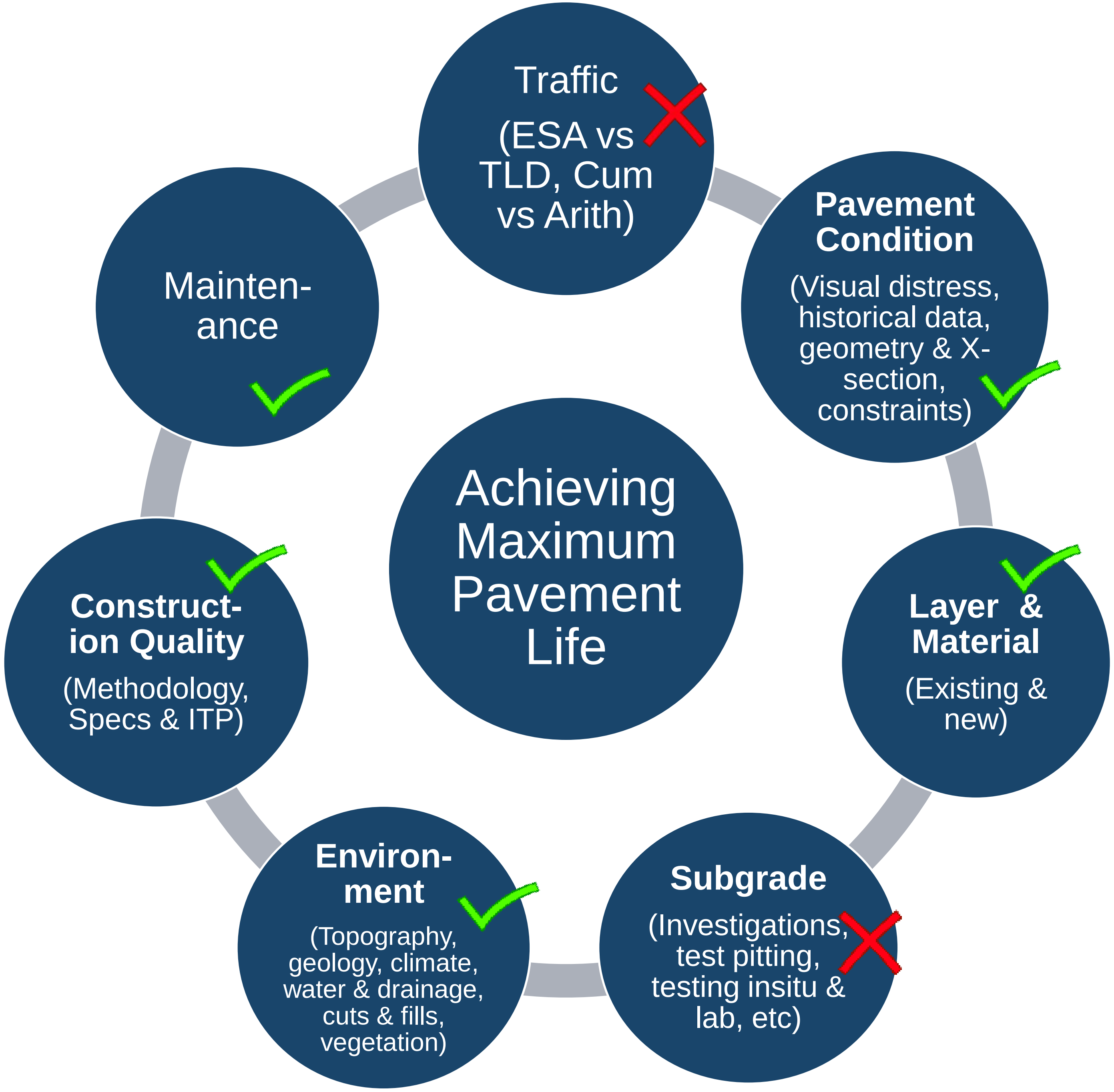
Most significant design-related factors affecting quality of roads:

"Nature and type of subgrade soil investigation"

Rahul R. Minde Dr. Anil N. Ghadge Analysing the factors influencing quality throughout the lifecycle of a road project.

Ahmed Ebrahim Abu El-Maaty, Ahmed Yousry Akal, Saad El-Hamrawy, "Management of Highway Projects in Egypt through Identifying Factors Influencing Quality Performance

And several other papers



Importance of good Sub-Grade Characterisation has been well understood for many years!

Austroads (1992) Procedures for the D...
Austroads (1992) procedu... with thin bituminous surfacin... design chart shown in Figu... designed to provide sufficient ... subbase course.

U.S. Department of Tra... Aviation Administration
"The importance of ac... and evaluation of pave... be overemphasized."

IRC:37
1.1 The first guidel... pavements, publish... based on (i) subgra... Bearing Ratio) and (... of number of comm... (having a laden weight of 3 tonnes or more) per day.

Fed Highway Administration: General Pavement Design Considerations (23 CFR 626) April 8, 1999.
...stiff, moisture and frost ...portant aspect of ...l attention needs to be ...stiffness and the ...ements on the NHS. When ..., clay or silt materials, ...00 mm should be

...rade, in terms of its stiffness, is the most ...n design thickness, composition and ...rade, the less the layer thicknesses and ...ired to carry given traffic loading. As ...y compaction to exploit the maxi- ... with the ...avoid over- ...onded fabric which can break

...shrinkage and changes in ...be separately treated to avoid ...eflecting through to the surface ...38). Such materials include *...reater* ...al and replacement with non- ...%) of depths up to 1 metre has ...such poor subgrade materials.
...e high performance surfacings, Adelaide,
...DIENTS OF AN UNBOUND GRANULAR PAVEMENT FOR A SUCCESSFUL SPRAYED SEAL,

There's ***little*** new in this presentation

"I want you to find a bold and innovative way to do everything exactly the same way it's been done for 25 years."

Subgrade

Support provided by subgrade is ***one of most important factors*** in determining pavement design thickness, composition and performance.

Support is dependent on ***soil type, density and moisture content*** at construction and in service!

Table 5.1: Use of subgrade support measures

Pavement type	Measure of subgrade support	
	CBR	Elastic parameters
Flexible	✓	✓
Rigid	✓	

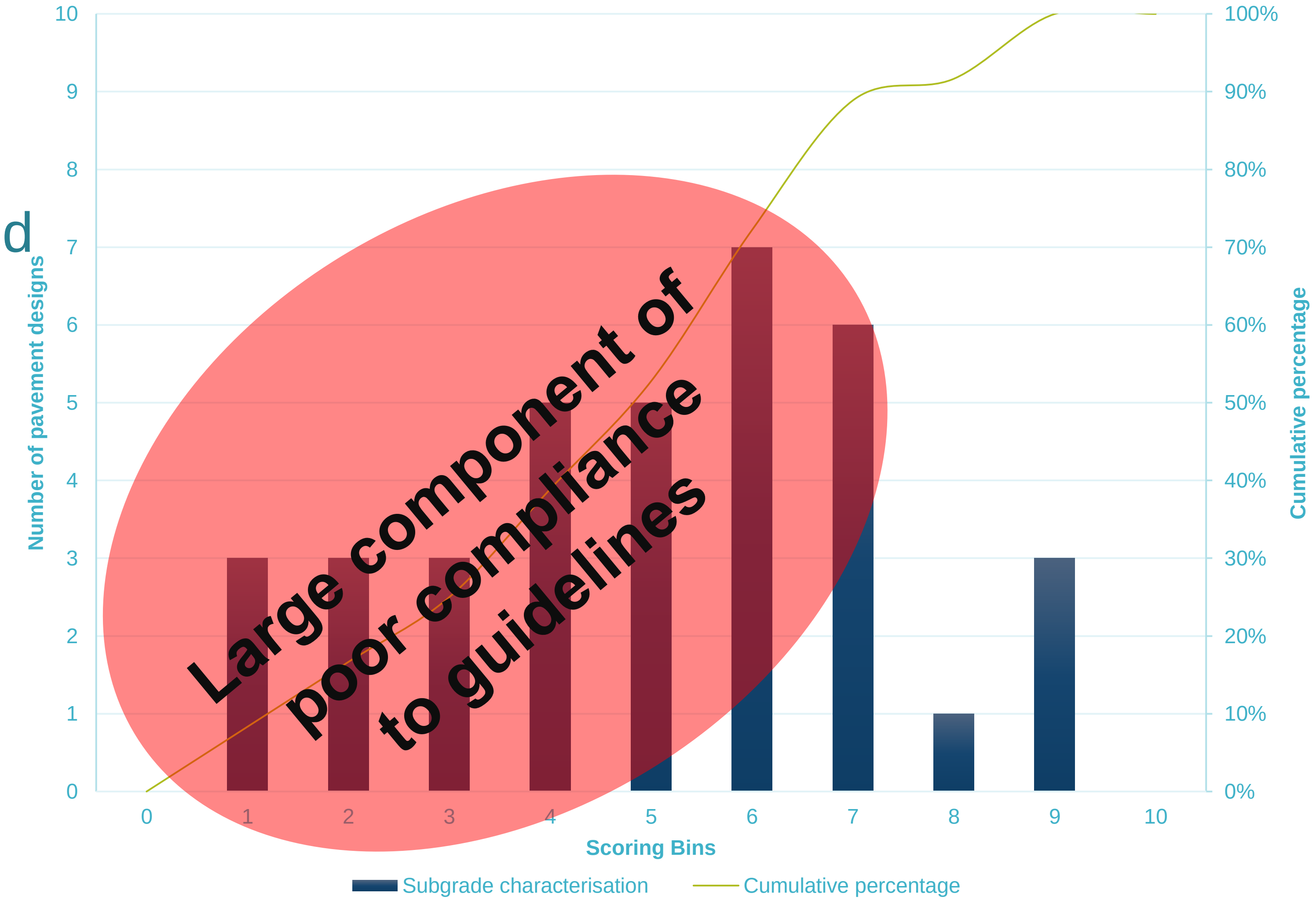
Guide to Pavement Technology Part 2: Pavement Structural Design, Ch 05

NZ / Austroads Best Practice

CH 05 Subgrade characterisation

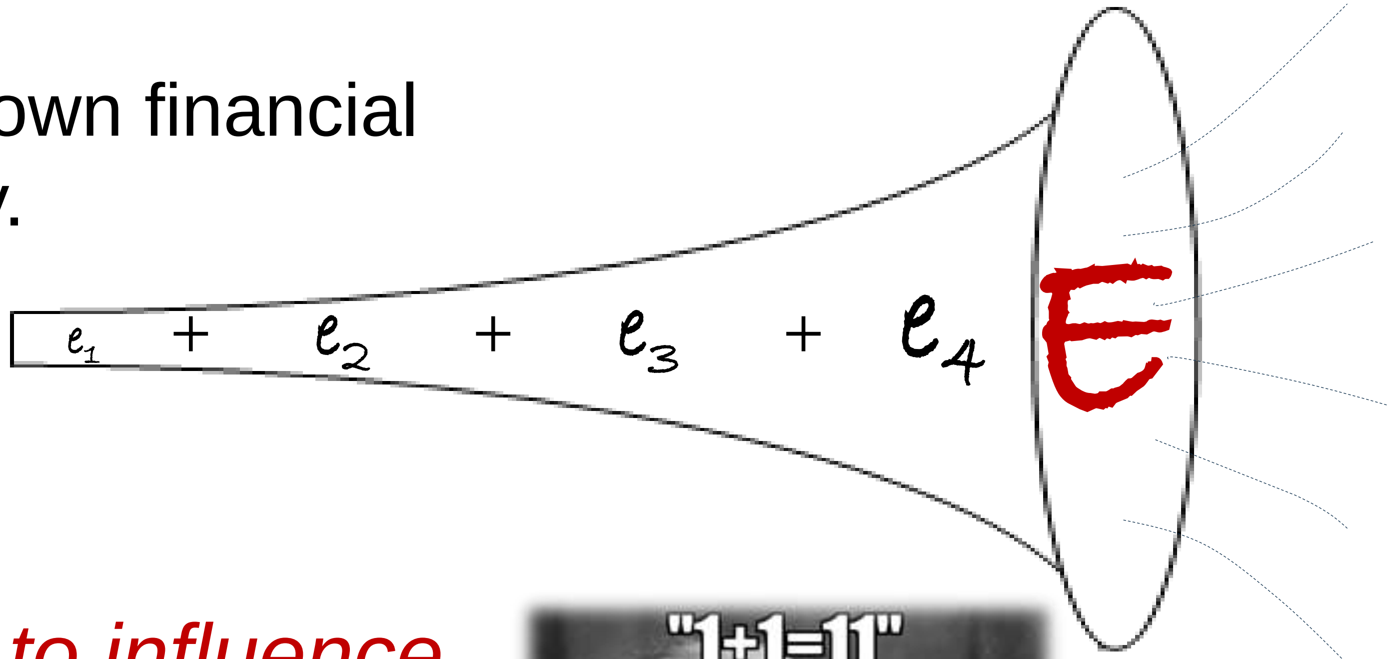
Depends on:

- HSD & FWD data analysis.
- Identification of TP sites and testing.
- Visual inspection.
- Site investigation.
- Insitu testing.
- Laboratory testing.
- Assignment of design modulus.

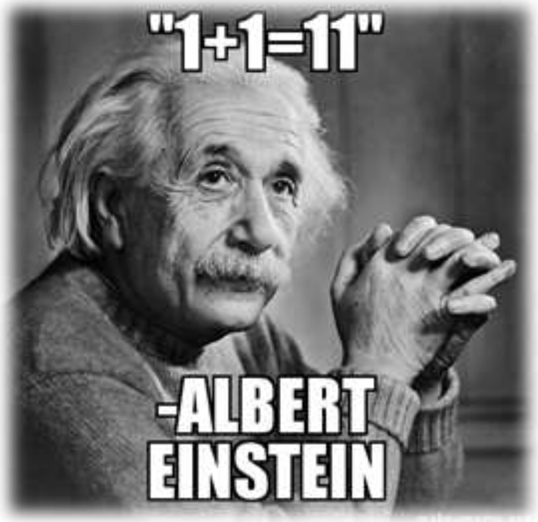


“Multiplier” Effect

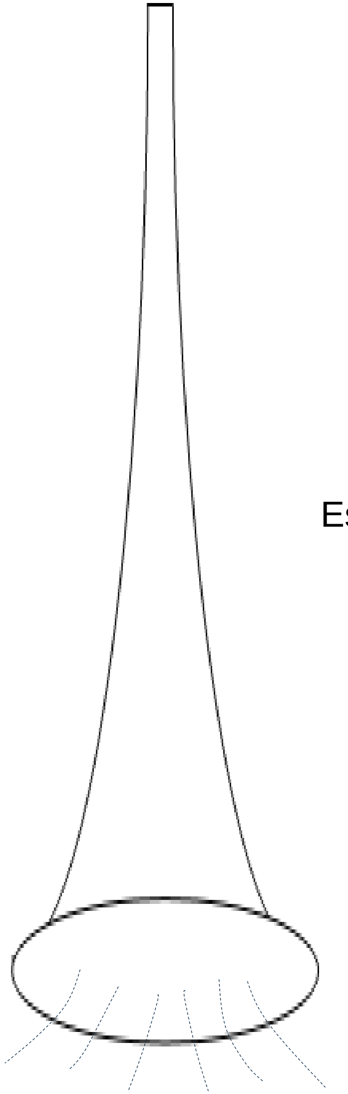
Multiplier effect is a well known financial principle and in error theory.



The *ability of one factor to influence a whole number of factors*, creating a *total much bigger than the sum* of the individuals.



“Multiplier eff



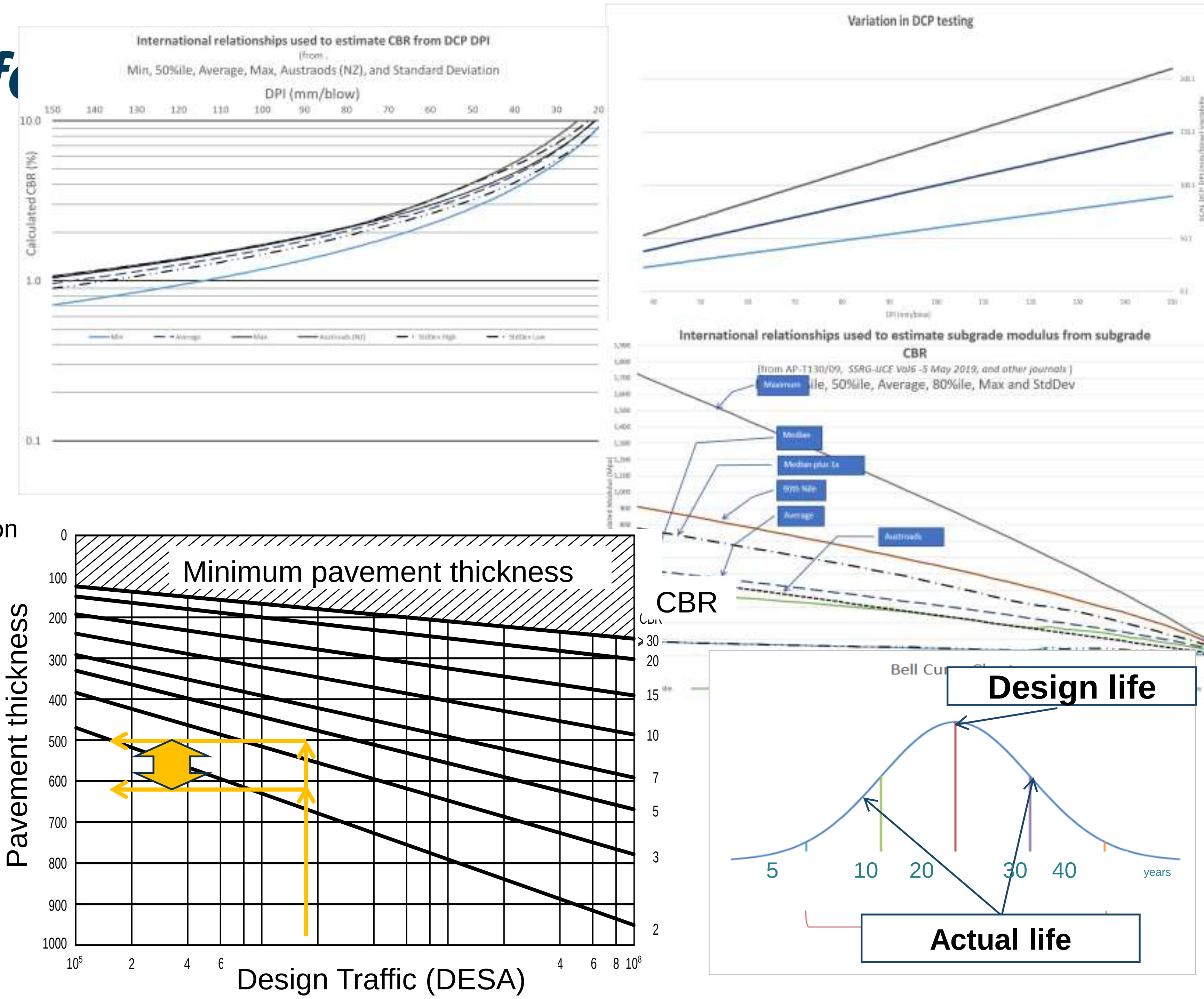
SCALA DCP subgrade strength inaccurately tested

Estimation of CBR from DCP

Estimation of Modulus Reaction (M_R) from CBR (inferred)

Over / under estimation pavement thickness

Pavement either over / under performs



Recent test pit investigations

What we have seen

Recent issues in pavement investigation

Test pit

- Generally done in dry season
- Seasonal variation not identified
- SG characterised stronger / weaker
- Too small
- Don’t reach subgrade

Scala DCP

- SG soil type & applicability of DCP
- SG characterised stronger / weaker
- Misidentification of M_R – N. Island volcanic
- DCP not recorded at SG start depth

Test Pit

Austroads / NZ guidance does not appear to be followed fully

Pavement moisture

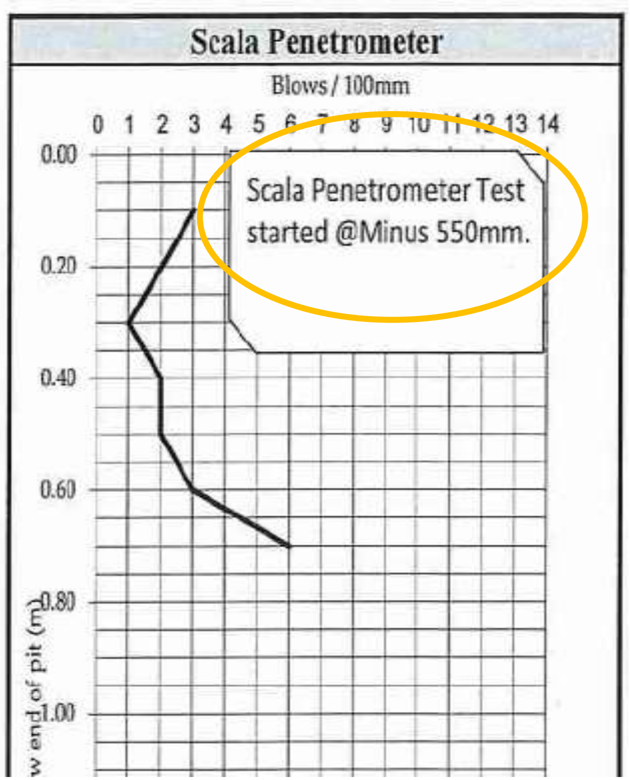
- Perched water table not identified!
- Sub-soil Drains not identified

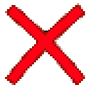
Vane shear

- Rarely done (in silt and clay)
- Moisture sensitive subgrades not identified

Test pitting

Depth (mm)	Pavement Description
45	CHIPSEAL: Worn, flushed & rutted.
220	BASECOURSE: AP40mm Angular crushed, sandy silty, greywacke GRAVEL. Re-worked, grey brown, dense, moist.
350	SUBBASE: AP120mm Angular crushed, sandy silty, greywacke COBBLES. Grey brown, dense, moist.
550	SUBGRADE : Medium SAND with minor fine to medium pumice gravel, orange brown, medium dense to loose, moist, pumiceous.
	End of Trench 2.





NZ Good practice:

Scala penetrometer testing should also always be used to identify any weak layers to a depth of at least 1m ***FROM*** the ***TOP of the subgrade.***

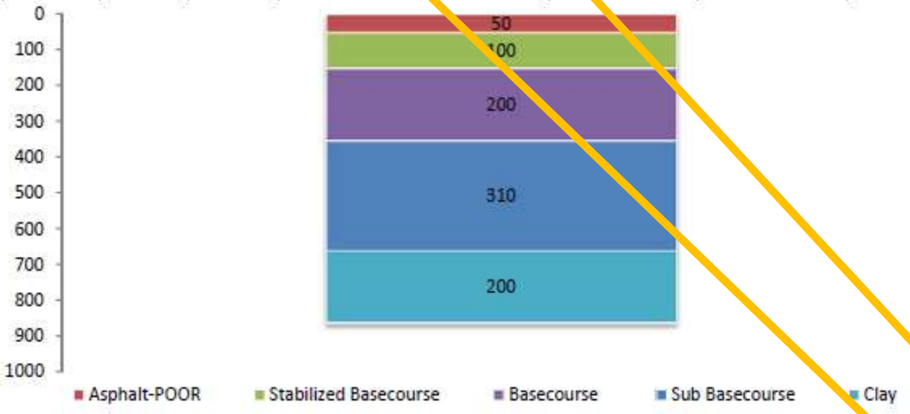
No knowledge of strength of upper subgrade on which we should be characterising the subgrade!

SITE INVESTIGATION TEST REPORT

[redacted]

Notes: Geonet found under Sub Base, cracking in Asphalt

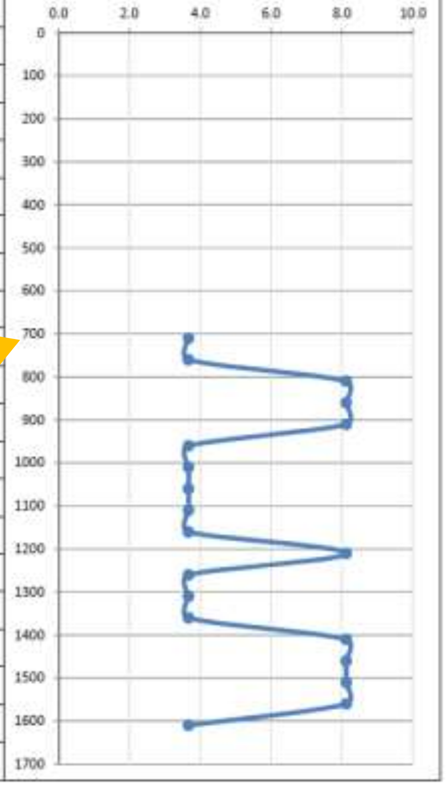
Layer	Depth (mm)		PRODUCT	Predominant Colour	Secondary Colour	Nominal Size (mm)	Rounded	Angular	Sub rounded	Sub angular	Soft	Firm	Very stiff	Hard	Dry	Moist	Wet	Saturated	Non Plastic	Slightly Plastic	Moderately Plastic	Highly Plastic	Well Graded	Fines Deficient	Excess Fines	Slightly Weathered	Moderately Weathered	Highly Weathered
1	0	50	Asphalt-POOR	BLACK																								
2	50	150	Stabilized Basecourse	GREY	BROWN	40				◇			◇			◇			◇				◇			◇		
3	150	350	Basecourse	BROWN	GREY	40				◇			◇				◇			◇			◇			◇		
4	350	660	Sub Basecourse	BROWN	GREY	160				◇			◇					◇			◇		◇			◇		
5	660		Clay	ORANGE	BROWN							◇						◇				◇						



Depth at commencement of Scala Penetrometer (mm)		660
Depth from surface (mm)	Blows per 50mm	Infer'd CBR (Austroads)
660	0	0.0
710	1	3.7
760	1	3.7
810	2	8.1
860	2	8.1
910	2	8.1
960	1	3.7
1010	1	3.7
1060	1	3.7
1110	[illegible]	3.7
1160	1	3.7
1210	2	8.1
1260	1	3.7
1310	1	3.7
1360	1	3.7
1410	2	8.1
1460	2	8.1
1510	2	8.1
1560	2	8.1
1610	1	3.7

NZS 4402: Test 6.5.2; Dynamic Cone Penetrometer

Inferred CBR formula used:
CBR = 324.51/ (mm/blow)^-1.1457 [derived form correlation chart in AUSTROADS PDG 1992, fig 5.2] Inferred CBR is not IANZ endorsed



NZ Good practice:

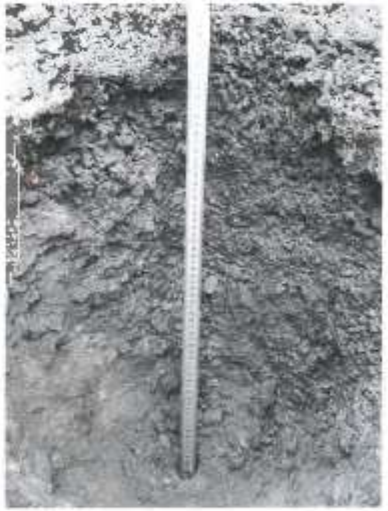
- ✓ Scala close to top of SG (40mm low)
- ✗ No nominal/max size
- ✗ No Shear vane??

Test pitting

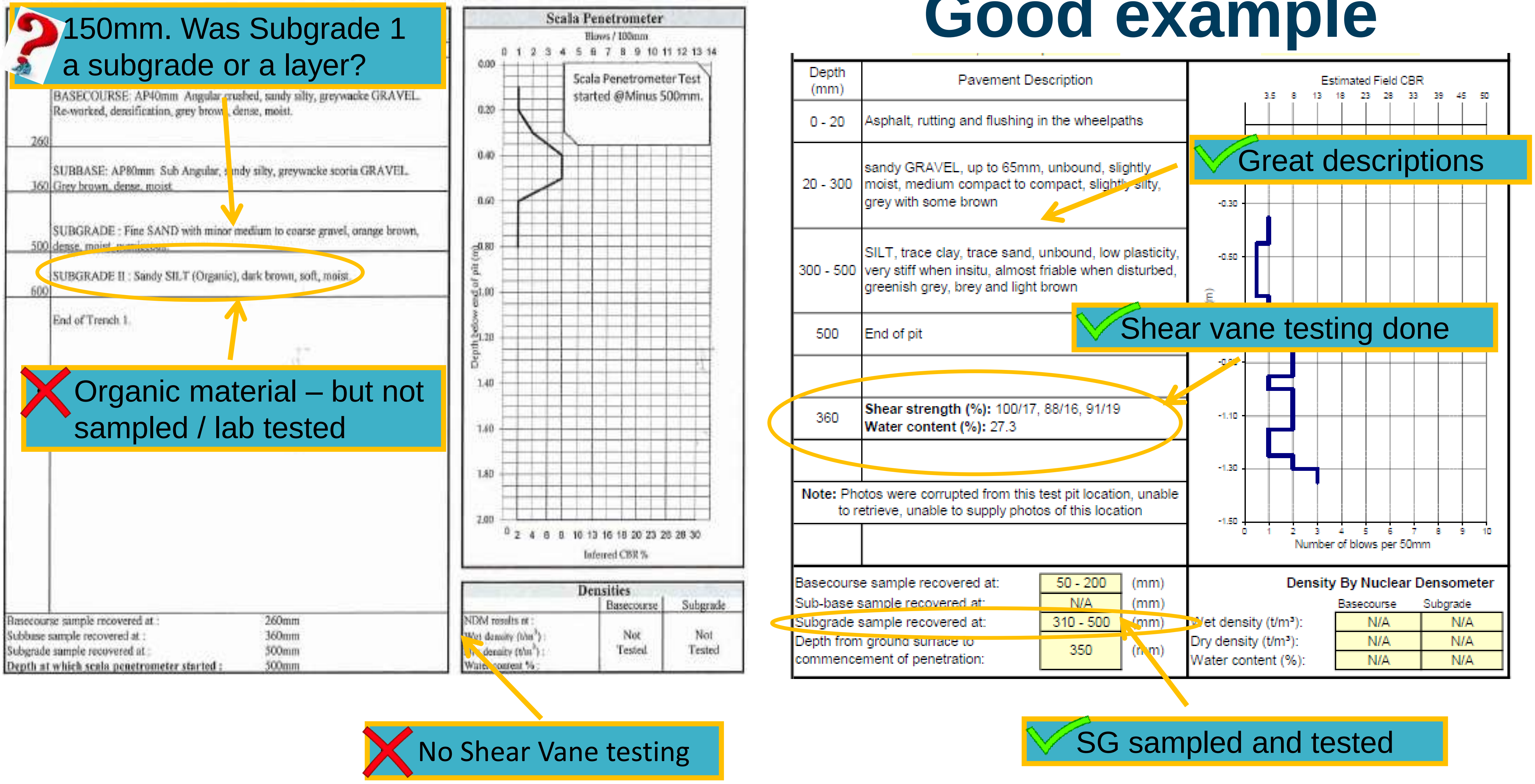
Depth (mm)	Description	Penetration Resistance Tests		
		Depth	Blows	CBR
0 40	SURFACE Chipseal Slightly flushing Scabbing of surface nearby	100 200 300		
40	GRAVEL, AP40 river gravel with moderate broken faces. Well compacted. Highly contaminated with grey silt. Unweathered, Unbound. Damp	Subgrade not reached		
600	Test pit ended.	Notes UTP - Unable to penetrate		

NZ Good practice:

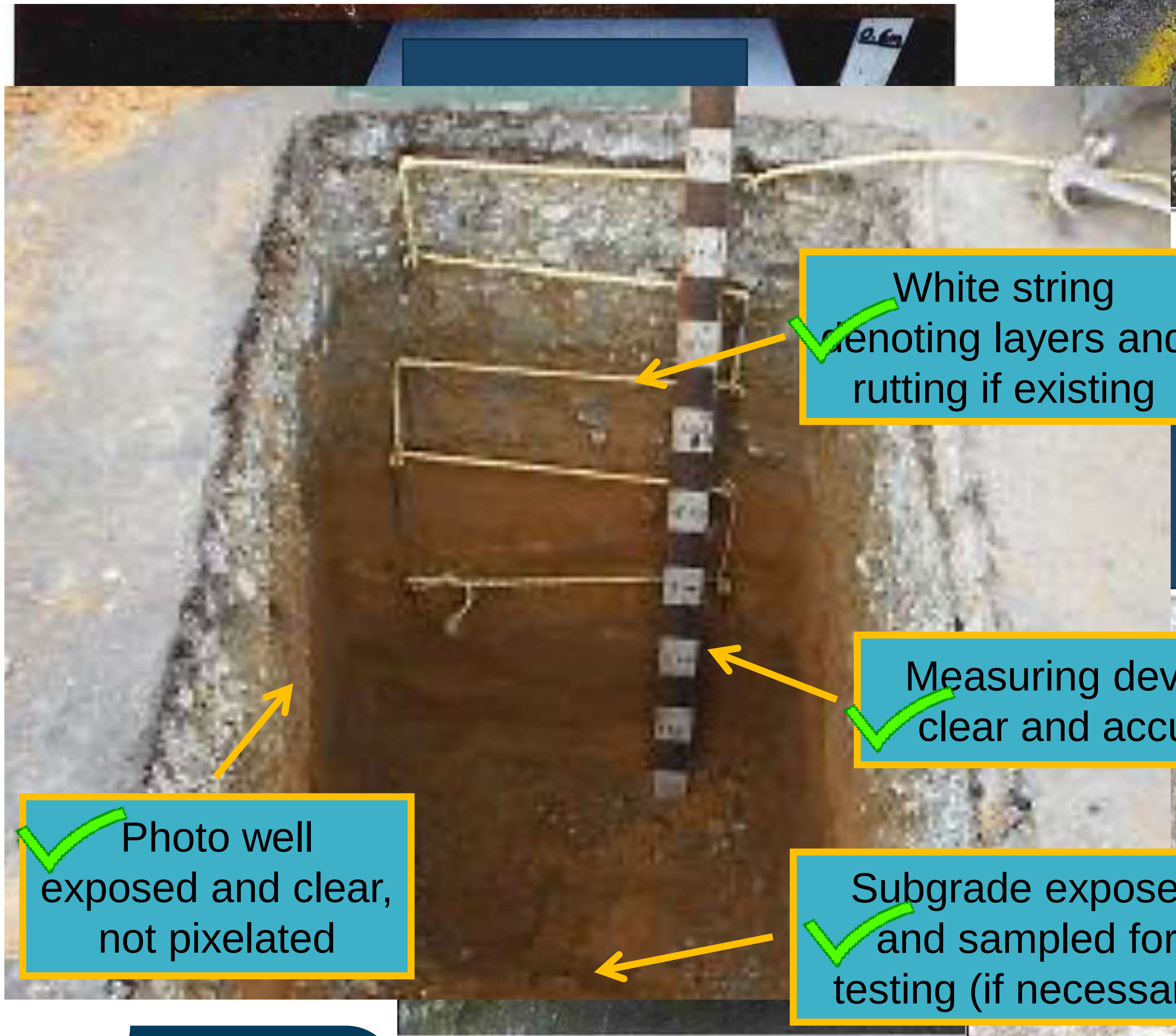
- ✓ Good descriptions
- ✗ Gravel – why try DCP?
- ✗ TP did NOT reach SG
- ✗ Test Pit VERY small!
- ✗ Tape measure impossible to read



Good example



Test pitting - Photos

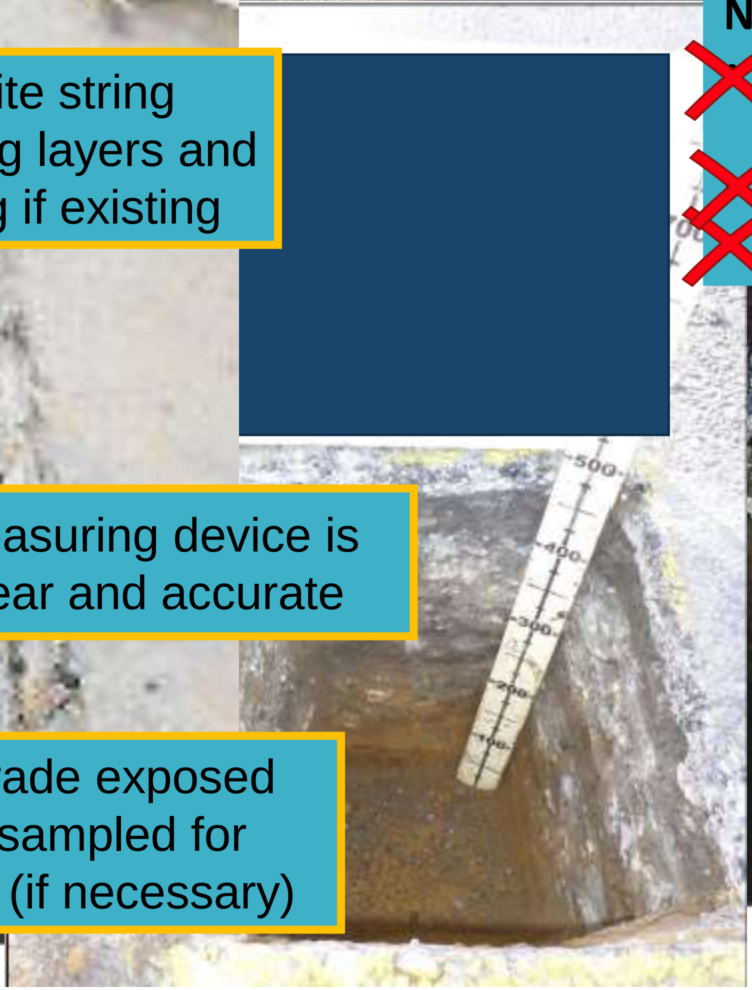


White string denoting layers and rutting if existing

Measuring device is clear and accurate

Photo well exposed and clear, not pixelated

Subgrade exposed and sampled for testing (if necessary)



NZ Good practice:

- Photos under/over exposed and/or poor quality
- Measuring devises unclear
- No Indication of layers

What do we need to improve?

- Investigations
- Test pits
- Insitu testing
- Laboratory testing

Level of investigation *MUST*

equal required level of performance risk

Balanced approach

Practical

Technical

Defensible

Traceable

Repeatable

“Accurate”

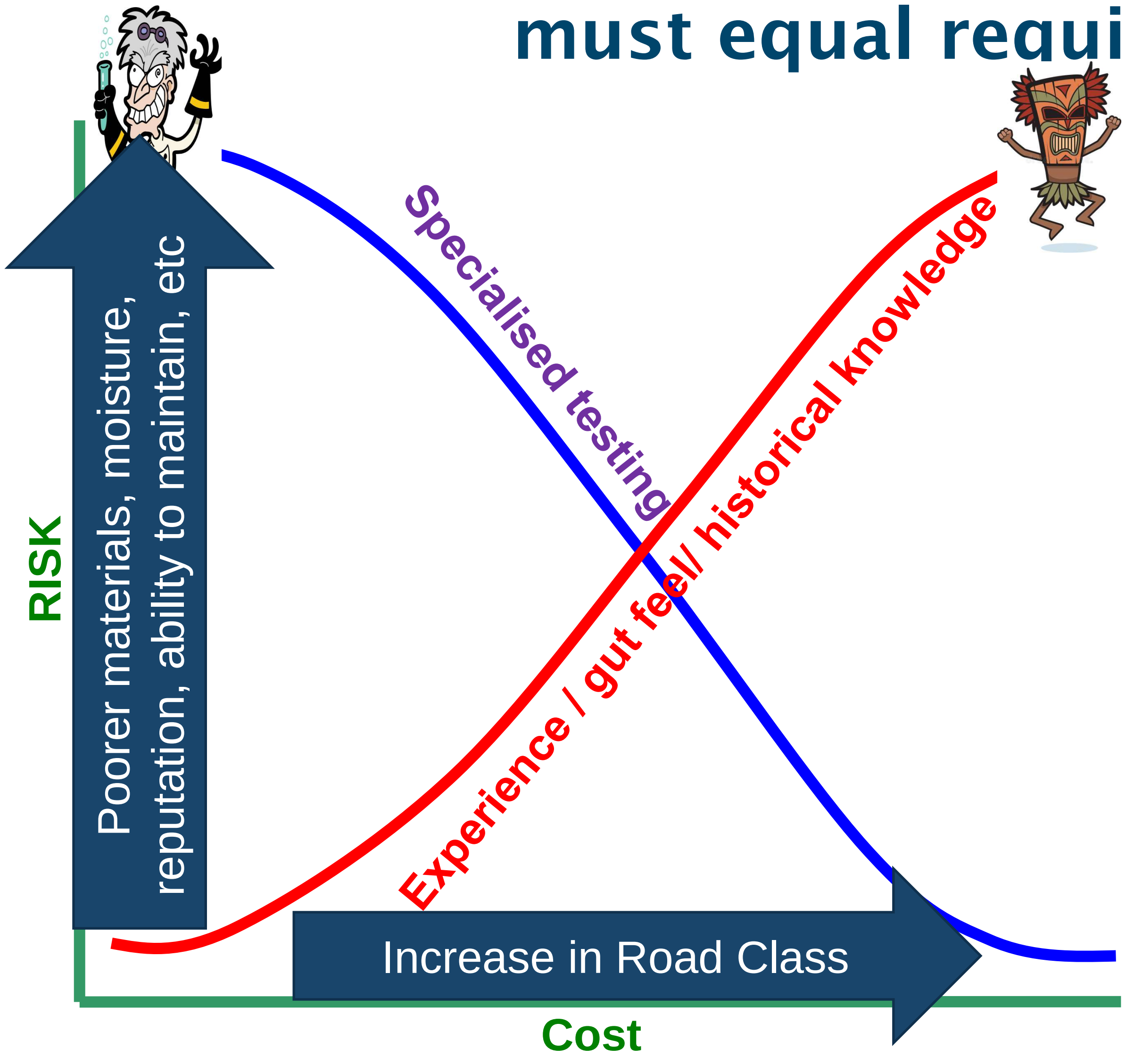
Adaptable

PRACTICAL
Gut feel & experience

TECHNICAL
Scientific principles and testing

Level of investigation

must equal required level of performance risk



- **Budget VS Risk.**
  - Enough TP & tests to have good idea of FMA.
  - Higher order roads, & larger projects = higher risk, = more test pits & testing...
- **Investigation & testing MUST identify:**
  - Material related risks MUST be identified
  - Additional sampling and testing if required.
- **Test Pits number MUST represent homogeneous sections:**
  - Both good and bad areas.
  - Defects mapping.
  - FWD analysis – uniform sections
  - Geology / fills &cuts / other anomalies.
  - Areas where moisture suspected.

BUT can only be reduced if risks are known and understood (previous test results, etc)

Test pits

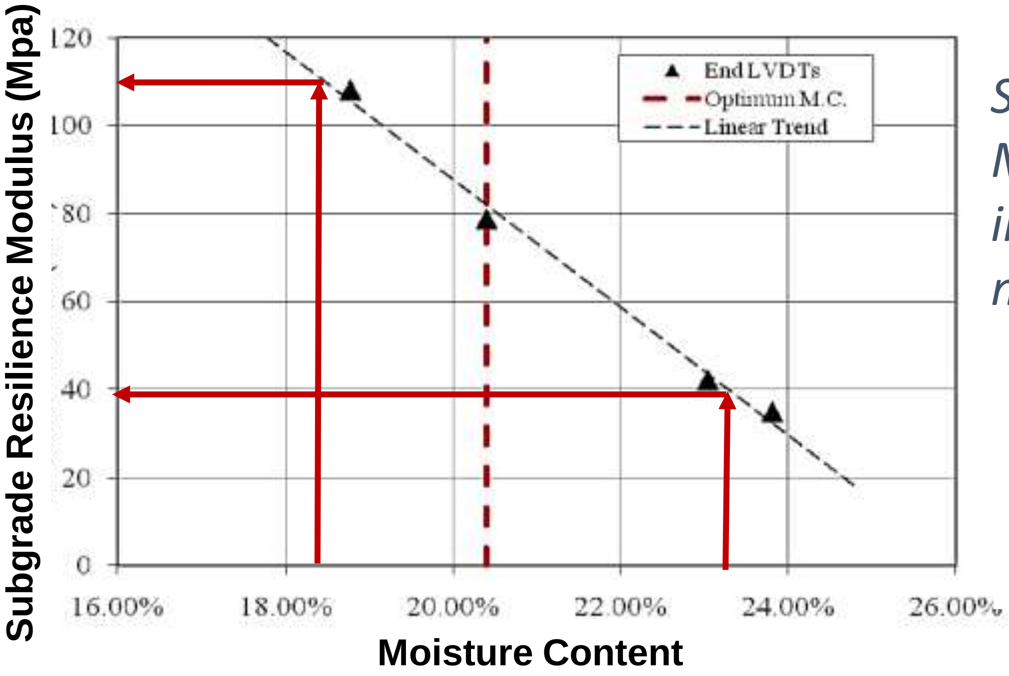
***MUST* identify:**

- **Visual assessment of layer characteristics**
- **Subgrade strength** (volcanic, clay, silt, sand, etc)
- **Subgrade variability** (topography, soil type)
- **Moisture changes** during service life
- **Drainage conditions**
  - **Presence of subsurface water**
  - **Depth** to the water table
- **Problem subgrades** - expansive or sensitive → addition sampling & testing.

Test pits

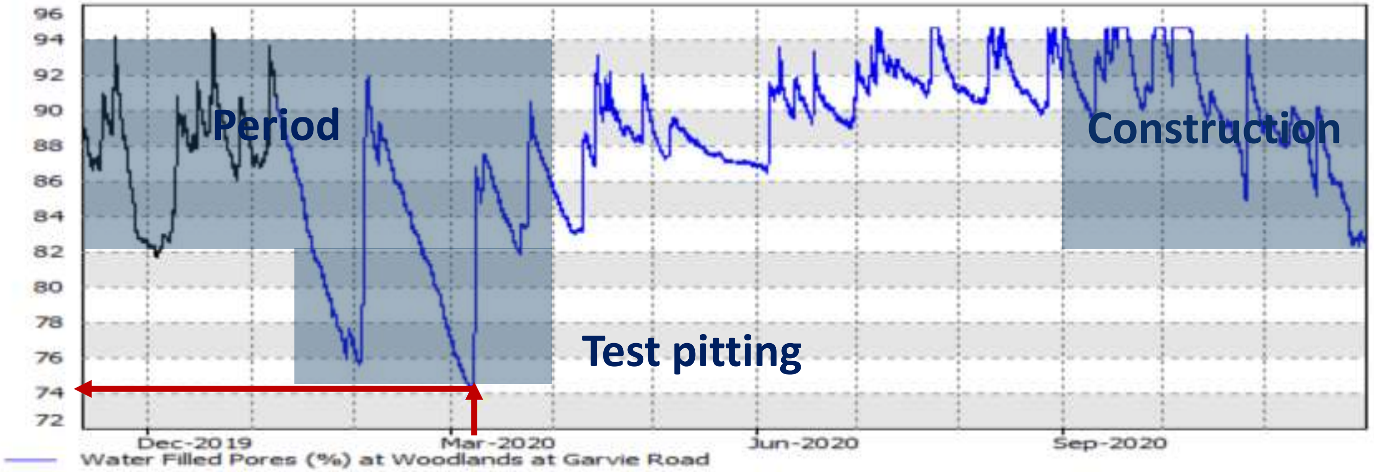
New Zealand guide to pavement evaluation and treatment design requires that test pits are:

- At least *400 mm × 1200 mm*.
- *To SG level*, and sampled after Scala DCP.
- Each layer material described *including moisture* - Field Description of Soils and Rock (NZGS 2005).
- TP ideally done at *wettest time of year*, OR dated clearly so seasonal moisture can be noted.



Subgrade Resilient Modulus variation in clay due to moisture content.

H Solimanand **A Shalaby**, ***"Sensitivity of Subgrade Resilient Modulus to Moisture Variation"***, Development of New Technologies for Classification of Materials Session, 2010 Annual Conference of the Transportation Association of Canada, Halifax, Nova Scotia.



Water filled pores for the construction and post construction. Note the water content at construction and test pitting.

http://envdata.es.govt.nz/index.aspx?c=soil-moisture&tab=graph

SG STRENGTH: SCALA DCP

Principal objective: Determine design subgrade CBR.

For the majority of soil types, best correlation with subgrade CBR (Scala DCP) from the Weighted Average blows/50mm for 1st three 50mm intervals:

- ✓ 0-50mm weighting: 0.7
- ✓ 50-100mm weighting: 0.2 and
- ✓ 100-150mm weighting: 0.1 for each interval.

Smits (1990)

- **START AT TOP OF SUBGRADE!**
- **RECORD SCALA AT blows/50mm INTERVALS.**
- **RECORD >1.2m BELOW PAVEMENT SURFACE**

Several Limitations:

1. Surcharge Loading
   - Material strength dependent on confining pressure and loading.
   - DCP in TP with surcharge loading removed - may not represent the insitu stren
2. Seasonal Moisture fluctuation
   - DCP CBR functional subgrade CBR.
   - Pavemer ≠ ndation @ testing, over-estimation of in-service moisture levels.
3. Non-cohesive & coarse materials (i.e. sand and gravels)
   - Multiple correlation methods, not accurately verified
   - Not considered a reliable method.
4. Fair correlation with fine-grained cohesive material.

FACTORS AFFECTING DCP RESULT

1. ALIGNMENT OF DCP RODS

- If rod is tilted during testing, resistance around the rod will increase.
- Also occurs if DCP rod penetrates through collapsible granular material.

2. DEPTH OF TESTING

- Test results very sensitive to depth of testing.
- If bottom rod of DCP is longer than standard rod, correction to DCPI value should be applied because vertical confinement and skin friction around the rod increases resistance to the penetrating rod.

3. DAMAGED CONE TIP

- If cone tip of the DCP is damaged it will give erroneous test results.

4. APEX ANGLE OF THE CONE

- Penetration rate significantly affected by cone apex angle.
- Penetration rates from DCP 30° are 10% greater than angle of 60°.

5. HAMMER WEIGHT

- The hammer weight exactly 8 kg.
- If weight is less, then rate of penetration will decrease and vice-versa.

6. LIFTING HEIGHT OF HAMMER

- If hammer not lifted to the top restraint plate and dropped freely, impulse force exerted will be reduced and the values of penetration decrease.

7. MOISTURE CONTENT

- DCP test results very sensitive to variations in moisture content.
- As moisture content increases, the penetration rate increases.
- DCP tests should be conducted at worst moisture content when the granular and sub-grade layers are softest and their minimum strength are recorded.

8. MATERIAL COMPOSITION

- DCPI varies with test material composition, soil class, coefficient of curvature, uniformity, density of the layer material and plasticity of the soil.

9. INTENSITY OF COMPACTION

- DCPI influenced by intensity of compaction and confinement of granular and subgrade layers.

Subgrade sensitivity – Shear Vane test

Measure of the loss of strength that occurs when the soil is disturbed or remoulded.
Only for clays and silty clays, especially when saturated.

$$\text{Shear Strength Ratio} = \frac{\text{Undisturbed shear strength or Peak strength}}{\text{Residual or Remoulded Shear Strength}}$$

Definition	Shear Strength Ratio
Insensitive	< 2
Moderately Sensitive	2 - 4
Sensitive	4 - 8
Extra Sensitive	8 - 16
Quick	>16

Table 2 Definition of soil sensitivity levels (NZ Geotechnical Society, 2005).

Greater Shear Strength Ratio = Greater risk subgrade loses strength due to traffic.

Planning for lab tests

*A man should look for **what is**,*
***not** for what he **thinks should be**.*

Albert Einstein, 1879 - 1955

Think openly… Ask:

- What data / information is available or can be inferred?
- Is it Structural **OR** Functional failure?
- Road environment?
- Potential rehab options?
- Material requirements of each option?
- Risk-based testing – more risk, more testing.
- Range of testing available
- Range of test result values expected for the sampled materials from logs.

Sampling

Requirements

- *Most neglected but most important aspect of testing.*
- Representative, full depth, full width.
- *Each layer* to be sampled but not necessarily tested.
- Sub-grade sampling only *after DCP & shear vane.*
- Lab Soaked CBR if *SG poor or sensitive.*
- Sample sizes large enough!
  - *>35kg if unknown testing or PSD & Indicator tests.*
  - *>60kg California Bearing Ratio.*

Atterberg Constants

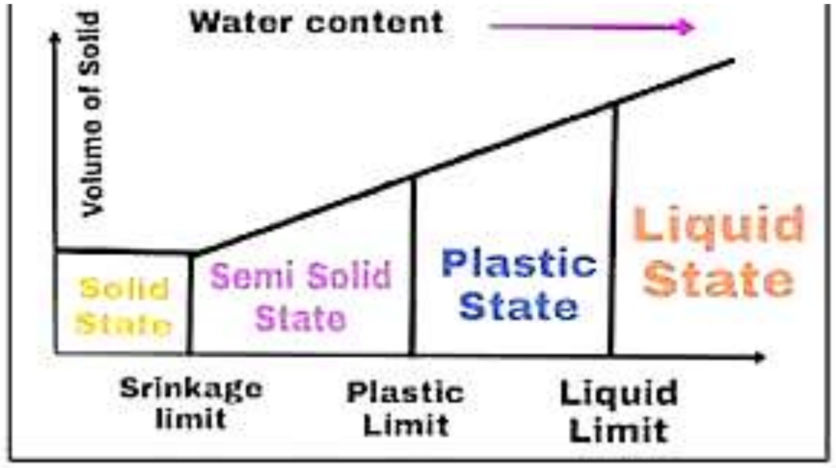
Critical part of investigation.

Expansive soils can cause loss of pavement shape due to moisture changes leading to pavement rehabilitation.

Table 5.2: Guide to classification of expansive soils *(Assessing tests NZ PET Ch 5.3)*

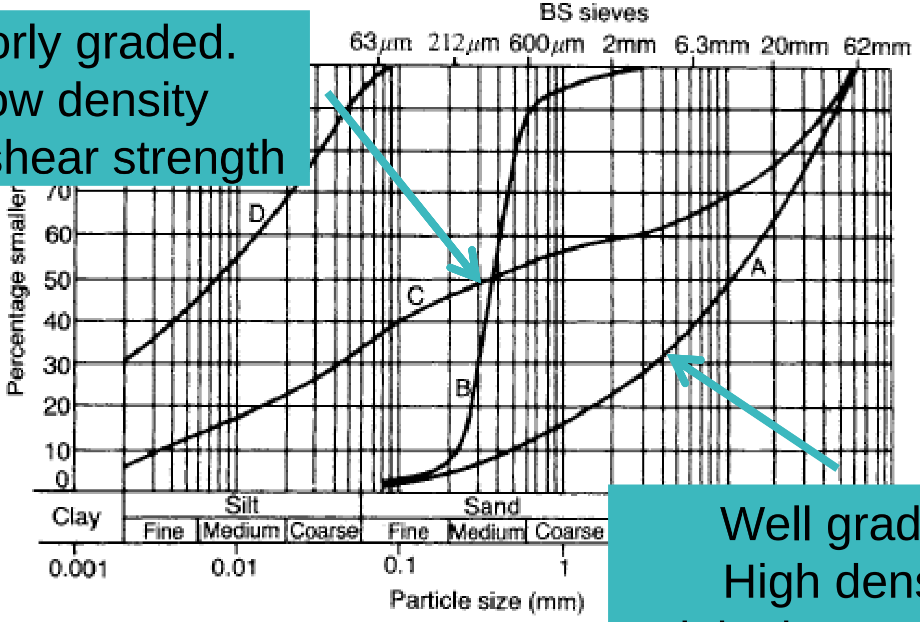
Expansive nature	Liquid limit (%)	Plasticity Index	PI x % < 0.425 mm	Swell (%) [1]
Very high	> 70	> 45	> 3200	> 5.0
High	> 70	> 45	2200–3200	2.5–5.0
Moderate	50–70	25–45	1200–2200	0.5–2.5
Low	< 50	< 25	< 1200	< 0.5

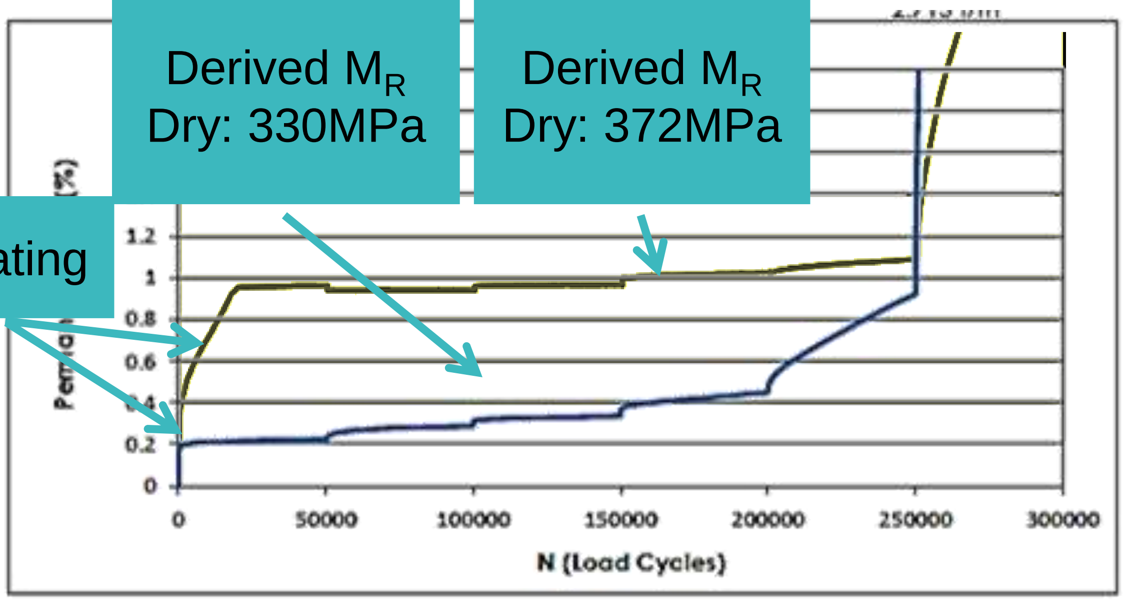
1 *Swell at OMC and 98% MDD using standard compactive effort; four-day soak. Based on 4.5 kg surcharge.*



Particle Size Distribution

- Basis of getting maximum density and maximum shear strength.
- Effects well understood for many years!





California Bearing Ratio

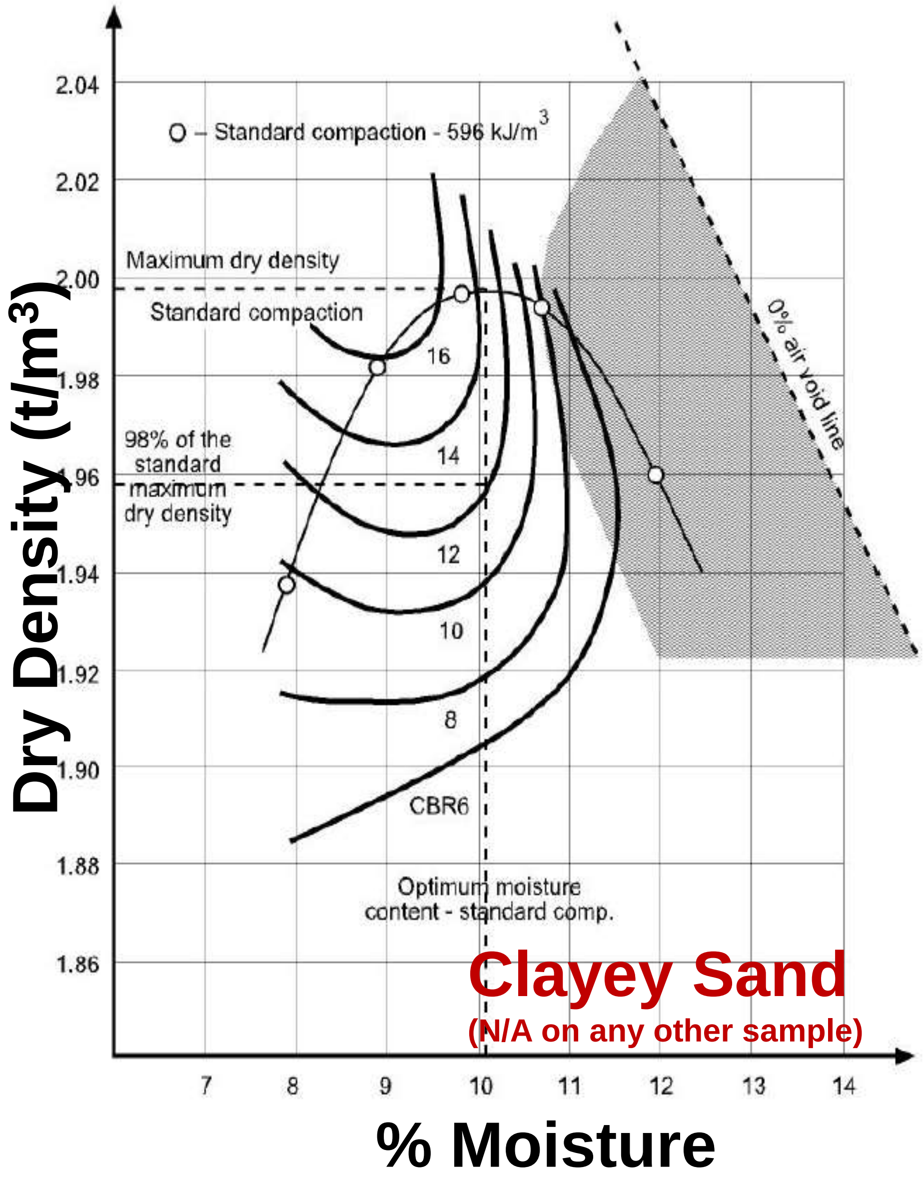


Figure 5.1: Example of variation of CBR with density and moisture content for clayey sand

Evaluates strength & moisture susceptibility.

Water content should be the equilibrium value

Soaked vs Unsoaked

- Soaked
  - Compulsory if Water Table <1m below seal or potential for flooding.
  - If sensitive or saturated clay
- Unsoaked: If low rainfall area or deep water table exists.

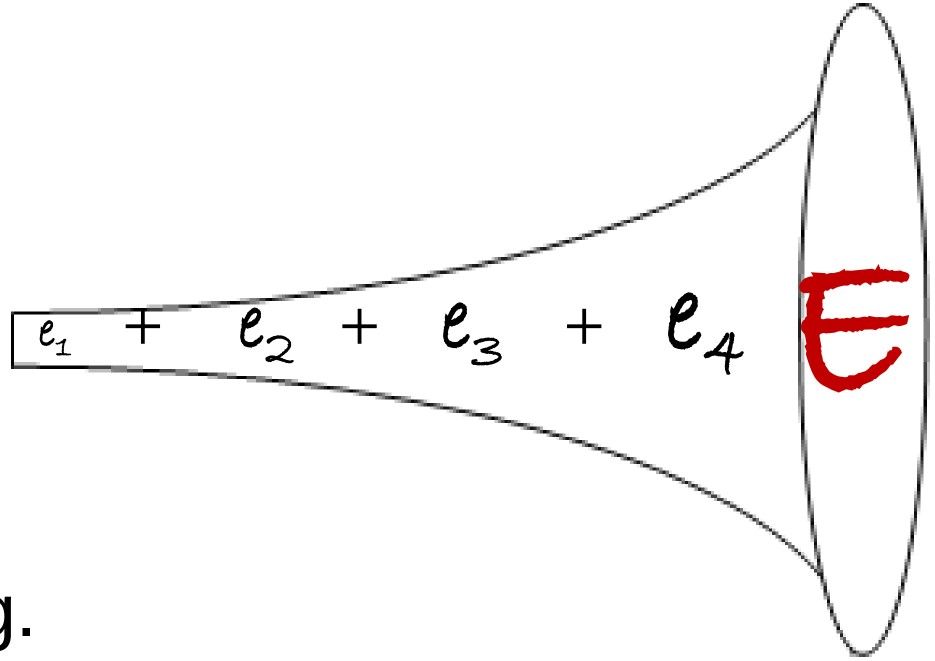
Test uncertainty is high

- Care needed - sampling to analysis
- No test limits in NZ unlike other countries.
- SANS 3001-GR40:2010 Maximum systematic error between labs
  $E = 3 + 0{,}01(CBR) + 0{,}0015(CBR^2)$
  - CBR 3% between CBR 1% and CBR 5%
  - MR between 10 and 50 MPa

In summary…

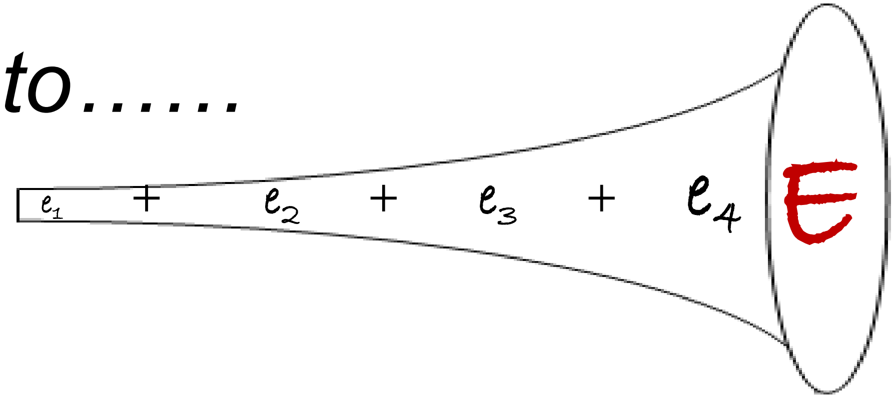
Understand!

- Potential rehab strategy.
- Risk vs budget.
- What you want out of the testing.
- What test limitations are.



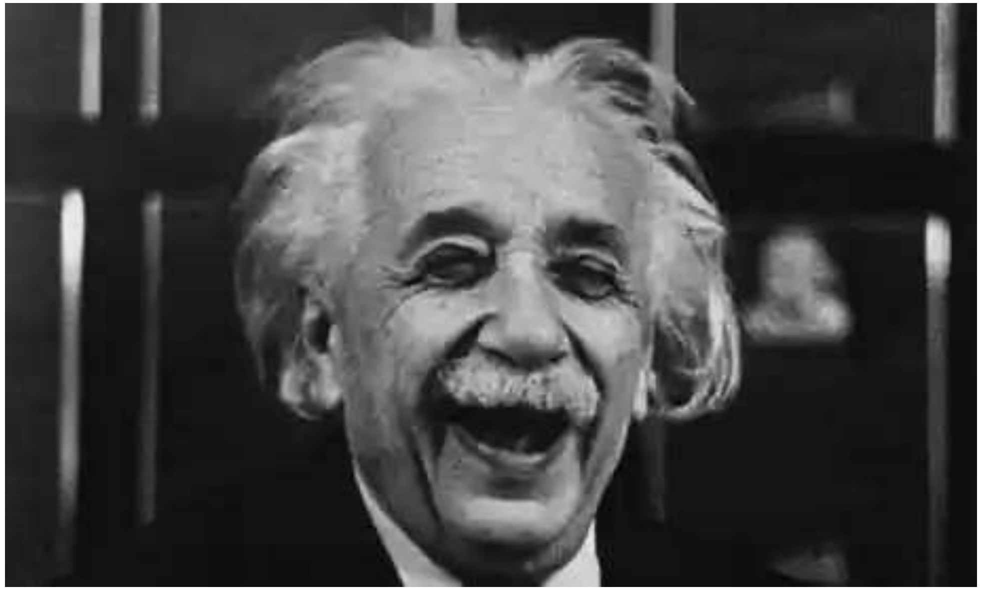
So that the resultant test errors reduce *from*…

to……



- Be open…
- Question everything!

"The important thing is to not stop questioning. Curiosity has its own reason for existing."



Albert Einstein, 1879 - 1955

"I have no special talent. I am only passionately curious."

"A man should look for ***what is,*** ***not*** *for what he* ***thinks should be".***