Ticking the Boxes to Quality Sustainable Roads or Are We?

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New Zealand - Scene

- Land Area – 263,310 km^2
- State Highways – Approx. 11,030 km …
- Local Authority – Approx. 53,940 km …
- Unsealed – Approx.31,860 km
- Budgets LA & NZTA :
  - Annual Maintenance - $2 000 000 000
  - Road Improvement - $2 000 000 000
- Global Roads Quality Ranking – 48 (2019)
- World Economic Forum – 40 (2017/18)

New Zealand – Roading Appreciation

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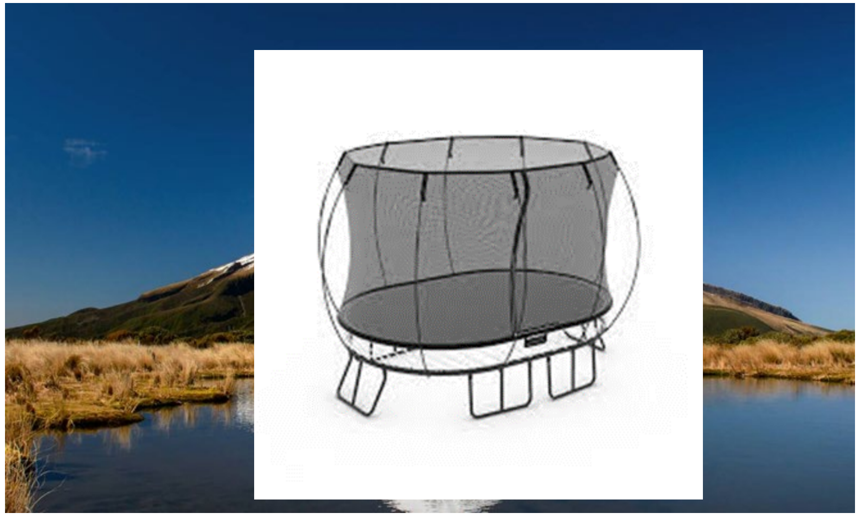
- Highest Rainfall – 18.4 metres (Hokitika West Coast)
  - Rain Days – > 130 + days a year
- Imports Freight(Deloitte Ports & Freight Yearbook)
  - 22,500 000 Tonnes
  - Geometric Growth – 3% Annually (2010-2020)
- Exports Freight(Deloitte Ports & Freight Yearbook)
  - 40,000 000 Tonnes
  - Geometric Growth – 3% Annually (2010-2020)
- Freight Main Mode of Transport
  - Trucks 93%
  - Rail 6%
- Inland Manufacturing and logistics not included
- Geology – Subgrades (Volcanic Ash, Pumice, Clay)
  - CBR 2 Quite Common



Quality Sustainable Roading Conundrum

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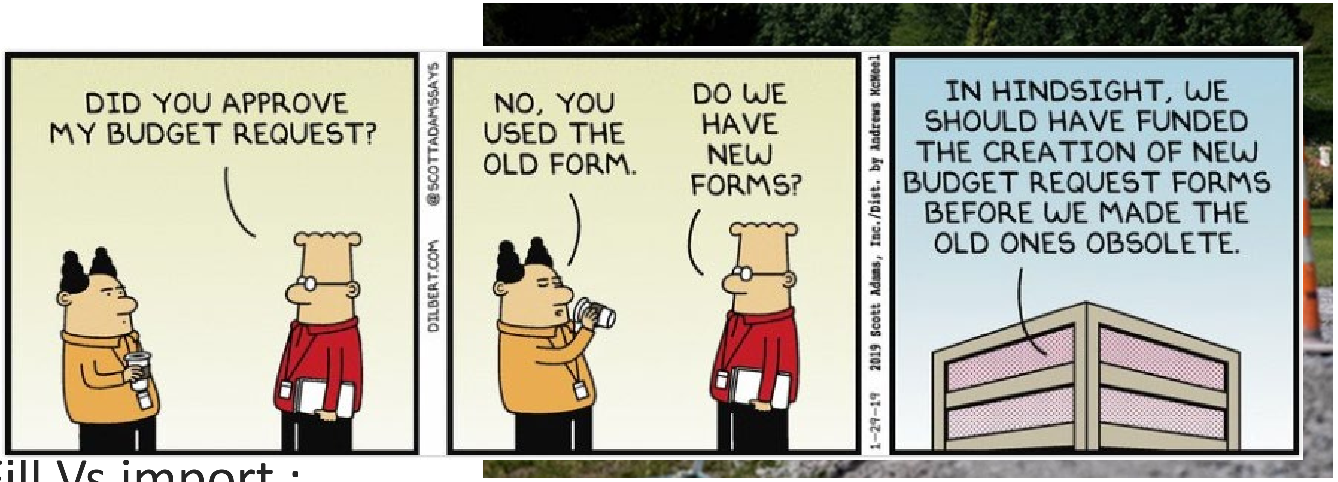
- Economies of Scale
- Road User Highest Priority
    - Disruptions Vs Long Term Pavement
- Budget Constraints, The skipping r
- Road history
    - Design Approach Geometric, Paver
    - Material Use Approach, e.g. Cut to Fill Vs import ;
    - Route Determination.
- Technology Barriers…..
- Environmental
    - Carbon Company/Country Ledger Approach – Skewed CO_2 Footprint



Pondering Onion

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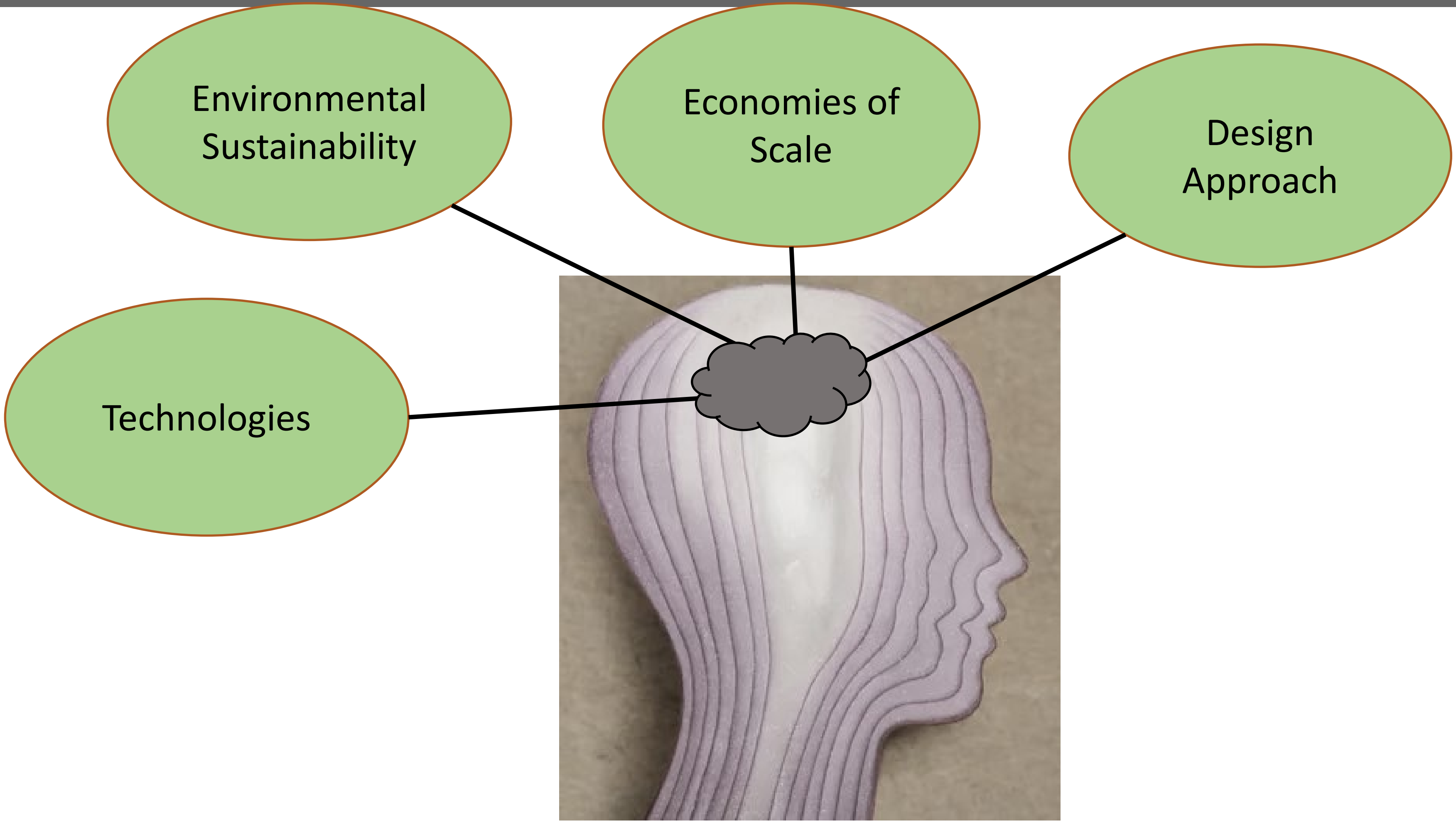

Economies of Scale

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Pavement Renewal Conglomeration

- More relevant statistical investigative approach;
- More opportunity for quality statistical relevant outcomes
- Improved P&G Vs Overall Cost Ratio;
- Lowered traffic management cost ratio;
- Material and production cost reductions;
- Longer term predictable asset management
- Opportunity to implement other pavement and surfacing technologies without budget prejudice

Design Approach: Engineering Judgement

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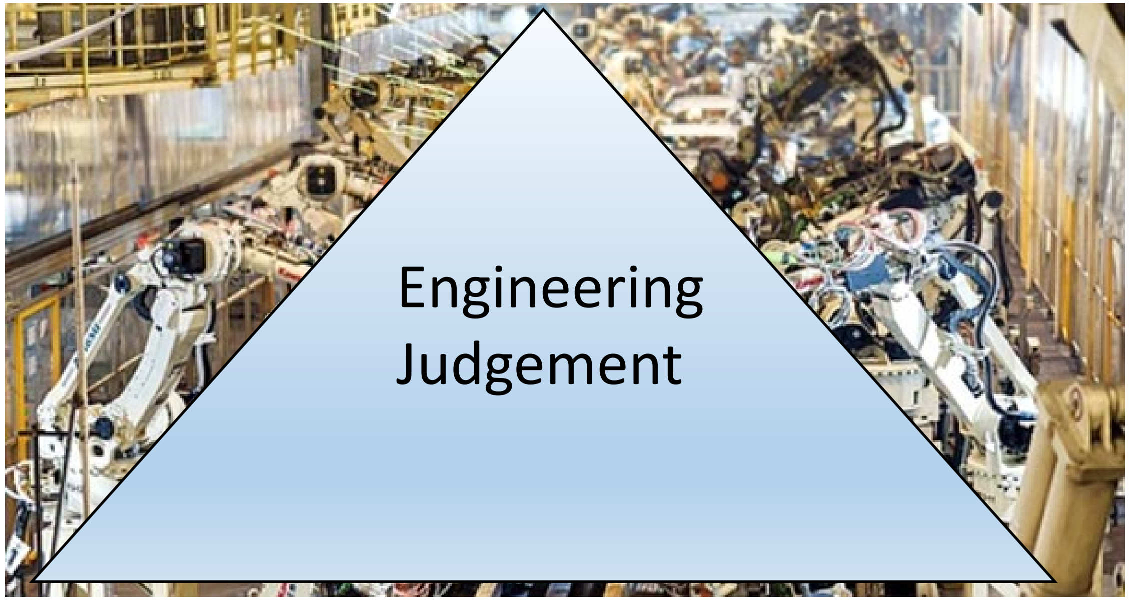
Applying intuition, insight and experience to devise an optimum solution to a complex engineering problem

Safety



Cost

Functionality

Design Approach – Asphalt Fatigue

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- Only required thicknesses of each layer (based on loading, moduli & other limited material properties)
- Does **NOT** assess if pavement treatment type is appropriate for rainfall & environmental conditions, temperature regime, materials available, % HCV, construction equipment & methodology, & practicalities of construction

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Damage Factor Calculation

Assumed number of damage pulses per movement:
   One pulse per axle (i.e. use NROWS)

Traffic Spectrum Details:

   ID: 20M DESA Title: 2.0e7 DESA

   Load   Load          Movements
    No.   ID
    1     ESA75-Full    2.00E+07

Details of Load Groups:

   Load   Load        Load        Load              Radius   Pressure/   Exponent
    No.   ID          Category    Type                       Ref. stress
    1     ESA75-Full  SA750-Full  Vertical Force     92.1     0.75        0.00

   Load Locations:
   Location   Load         Gear        X          Y      Scaling     Theta
    No.       ID           No.                           Factor
    1         ESA75-Full    1        -165.0      0.0    1.00E+00     0.00
    2         ESA75-Full    1         165.0      0.0    1.00E+00     0.00
    3         ESA75-Full    1        1635.0      0.0    1.00E+00     0.00
    4         ESA75-Full    1        1965.0      0.0    1.00E+00     0.00

Layout of result points on horizontal plane:
   Xmin:  0   Xmax:  2000   Xdel:  10
   Y:     0

Details of Layered System:

   ID: CNC_QEIII1 Title: CNC QEII Interchange Pavement Alt Rough

   Layer  Lower    Material    Isotropy  Modulus   P.Ratio
    No.   i/face   ID                    (or Ev)   (or vvh)  F          Eh         vh
    1     rough    Asph1250    Iso.      1.25E+03  0.40
    2     rough    Asph3000    Iso.      3.00E+03  0.40
    3     rough    Gran_150    Aniso.    1.50E+02  0.35      1.11E+02   7.50E+01   0.35
    4     rough    subsltCB10  Aniso.    1.00E+02  0.45      6.90E+01   5.00E+01   0.45
    5     rough    Sub_CBR5    Aniso.    5.00E+01  0.45      3.45E+01   2.50E+01   0.45

   Performance Relationships:
   Layer  Location Performance Component  Perform.  Perform.  Traffic
    No.            ID                     Constant  Exponent  Multiplier
    1     bottom   Asph1250    ETH         0.003920   5.000     1.000
    2     bottom   Asph3000    ETH         0.004067   5.000     1.000
    4     top      selAus2004  EZZ         0.009300   7.000     1.200
    5     top      Sub_2004    EZZ         0.009300   7.000     1.200

   Reliability Factors: Not Used.

   Details of Layers to be sublayered:
   Layer no.  3:  Austroads (2004) sublayering
   Layer no.  4:  Austroads (2004) sublayering

Results:

   Layer  Thickness  Material    Load         Critical     CDF
    No.              ID          ID           Strain
    1       40.00    Asph1250    ESA75-Full   -2.50E-05    2.12E-04
    2      210.00    Asph3000    ESA75-Full   -1.42E-04    1.04E+00
    3      160.00    Gran_150                  n/a         n/a
    4      300.00    subsltCB10  ESA75-Full    2.55E-04    2.77E-04
    5        0.00    Sub_CBR5    ESA75-Full    2.66E-04    3.78E-04
```

Design Approach:
Brief History of Asphalt Fatigue Criterion

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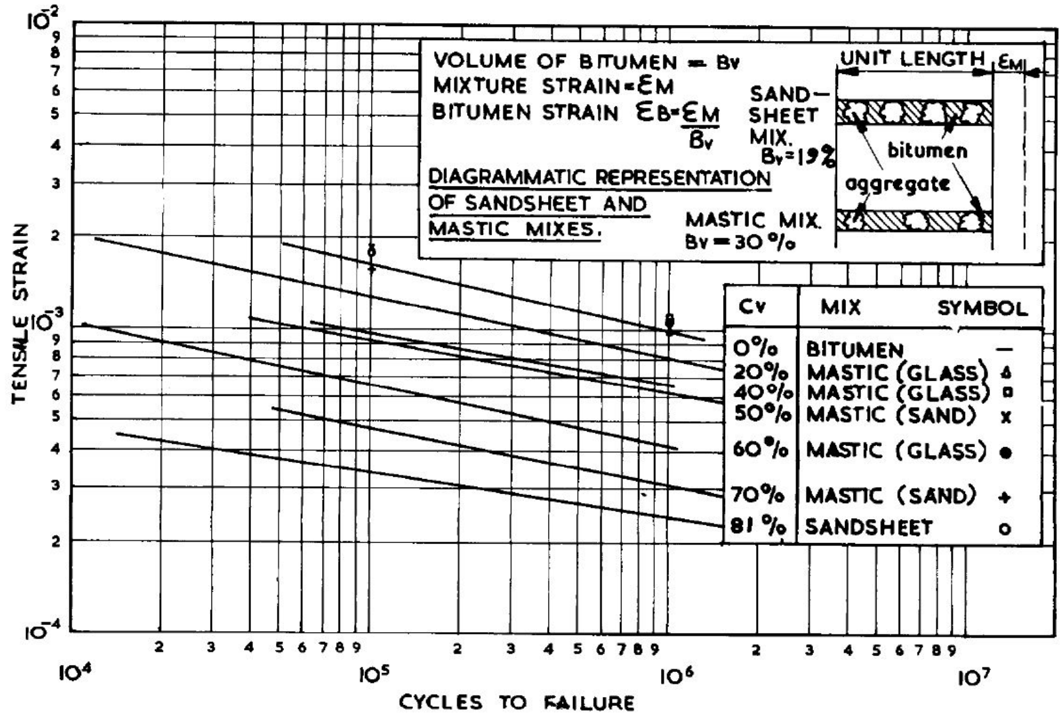
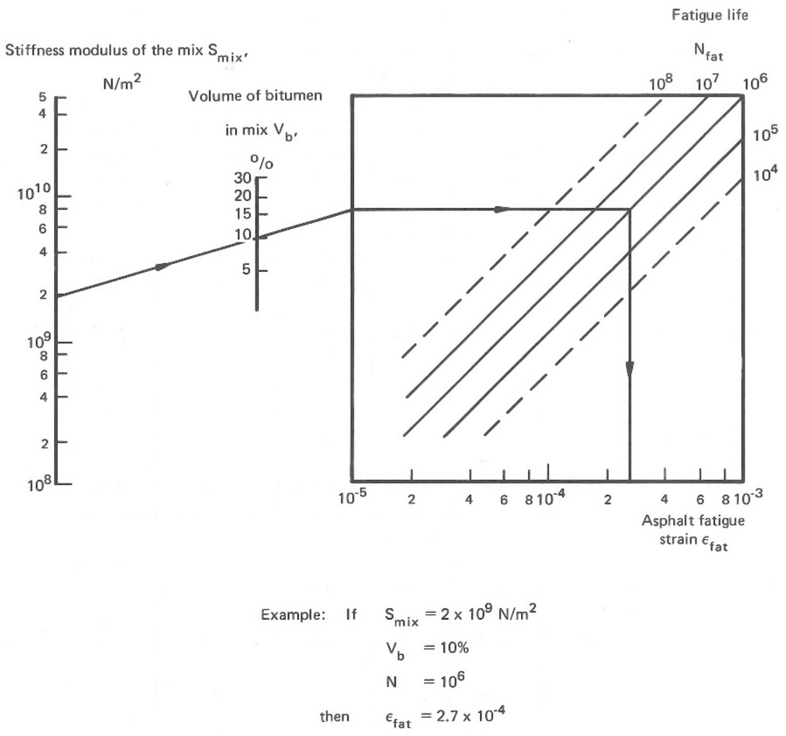
Pell, P.S. (1962) Fatigue Characteristics of Bitumen and Bituminous Mixes. Int'l Conference on Structural Design of Asphalt Pavements, Ann Arbor, USA



Van Dijk, W & Visser, W (1977) Energy approach to fatigue for pavement design. Asphalt Paving Technology, Vol. 46, pp. 1-39



Design Approach:
History of Asphalt Fatigue Criterion

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2. The first approach

Nomograph: Fig. A3.1

The fatigue data on different bituminous mixes* cover a large range of mix types (see Table A3.1 for some examples) and of testing conditions.

For a given mix, the fatigue curves, represented by $N_{fat} = k \times \varepsilon_{fat}^{-n}$ (k and n being mix constants), obtained at several temperatures have different slopes (n-values) in a log N_{fat}-log ε_{fat} plot. No simple correlations have yet been found between these slopes and the mix characteristics. Some approximations therefore have to be made.

First approximation

Assume that the slopes of the fatigue curves have the same value, n = 5.

By interpretation of the fatigue measurements it is found that the fatigue strain (ε_{fat}) for failure after a fixed number of loading cycles (N_{fat}) is a function of the mix stiffness modulus S_{mix}. These curves, on a log-log scale, can be considered as straight lines.

No simple relationship between the slopes of these lines and mix characteristics has been found. Therefore, in a *second approximation*, assume that the slopes of the log ε_{fat} versus log S_{mix} relation are all equal to −0.36, so that:

$$\log \varepsilon_{fat} = -0.36 \log S_{mix} + \text{constant} \qquad (1)$$

for a fixed number of loading cycles.

The value of the constant has been determined from the measurements. It has been found that the fatigue strain for failure at 10^6 cycles $(\varepsilon_{fat})_{N=10^6}$ for a mix stiffness modulus of 5×10^9 N/m² increases as the volume of the bitumen in the mix (V_b) increases in accordance with the equation:

$$(\varepsilon_{fat})_{N=10^6} = (17.4 \times V_b + 22) \times 10^{-6} \qquad (2)$$

* See ref. 5 in the Bibliography.

From equations (1) and (2):

$$(\varepsilon_{fat})_{N=10^6} = (17.4 \times V_b + 22) \times 10^{-6} \times \left(\frac{S_{mix}}{5 \times 10^9}\right)^{-0.36} \qquad (3)$$

According to the first assumption, $N_{fat} = k \times \varepsilon_{fat}^{-n}$ and n = 5, so:

$$\varepsilon_{fat} = (\varepsilon_{fat})_{N=10^6} \left(\frac{N_{fat}}{10^6}\right)^{-0.2} \qquad (4)$$

Finally, from equations (3) and (4):

$$\varepsilon_{fat} = (0.856 \times V_b + 1.08)\, S_{mix}^{-0.36} \times N_{fat}^{-0.2} \qquad (5)$$

Equation (5) has provided the basis for a nomograph, shown in Fig. A3.1, from which the permissible asphalt strain ε_{fat} can be predicted when two parameters are known:

- the stiffness modulus of the asphalt mix, S_{mix}, N/m² (see Appendix 2);
- the volume of the bitumen in the mix, V_b, % (see Appendix 2).

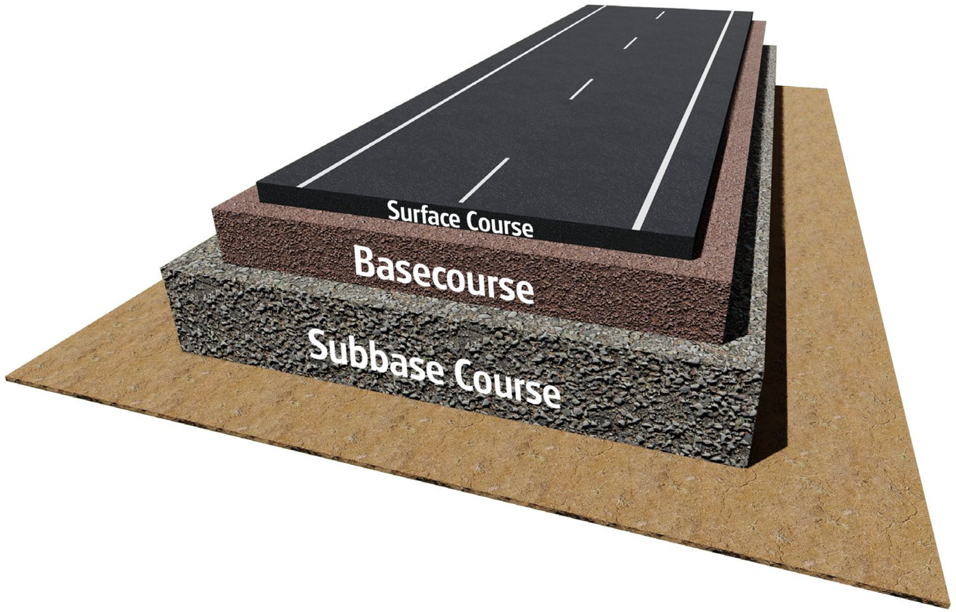
$$N = F\left[\frac{6918(0.856\, V_B + 1.08)}{S_{mix}^{\;0.36}\, \mu\varepsilon}\right]^5$$

Shell International Petroleum (1978) Pavement design manual: asphalt pavement and overlays for road traffic. Shell International Petroleum Company, London, UK

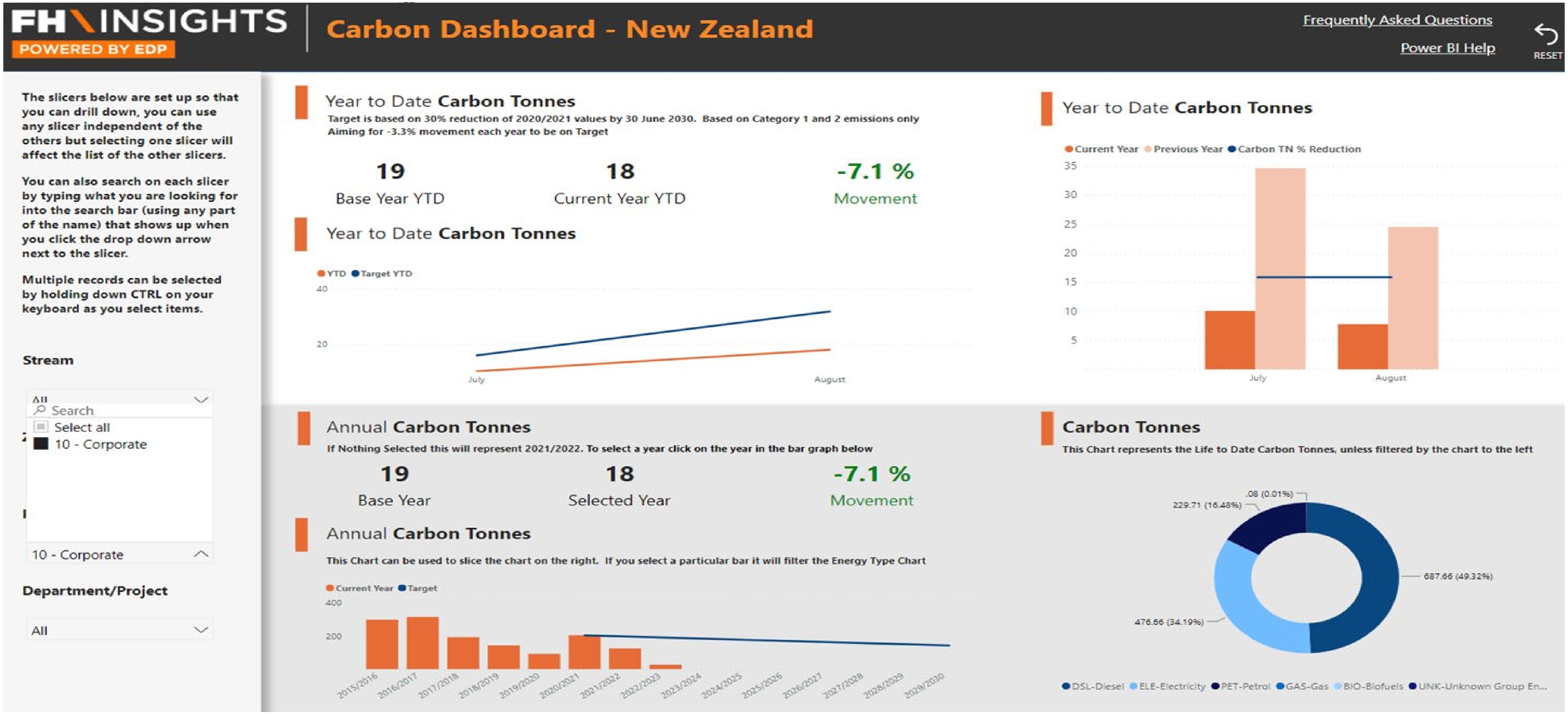
Design Approach: Granular Pavements

- Scala, Recording every 100 mm or 50mm
  - Low resolution in poor subgrades
  - Alternative - mm/blow
  - Unbound Granular Compaction and support
  - CBR 3 Subgrade ≠ Subbase Spec 95% Average of MDD ?
- Volcanic Soils ≠ Benkelman Beams

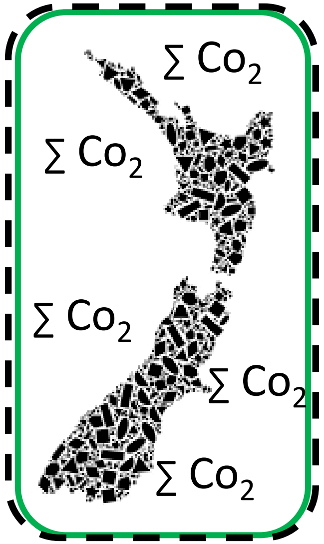
- Statistical Approach if possible
- CIRCLY is a Model, Models need to representative
- Fig 8.4 Vs Deflections Vs Asphalt wearing course

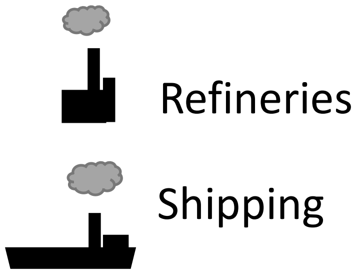


Environmental – Food For Thought



Environmental – Food For Thought





Asphalt Constituents

1. Aggregates (New)
2. Bitumen (New)
3. RAP (Bitumen & Aggregates)

Carbon Credits :

- Aggregate and Bitumen in RAP up to 40% by weight of the asphalt mix

Carbon Not Accounted For :

- Refinery Emissions
- Shipping Emissions

- Carbon Counting Food for Thought: Importation does carry a burden on the environment, RAP waste does not get enough lime light

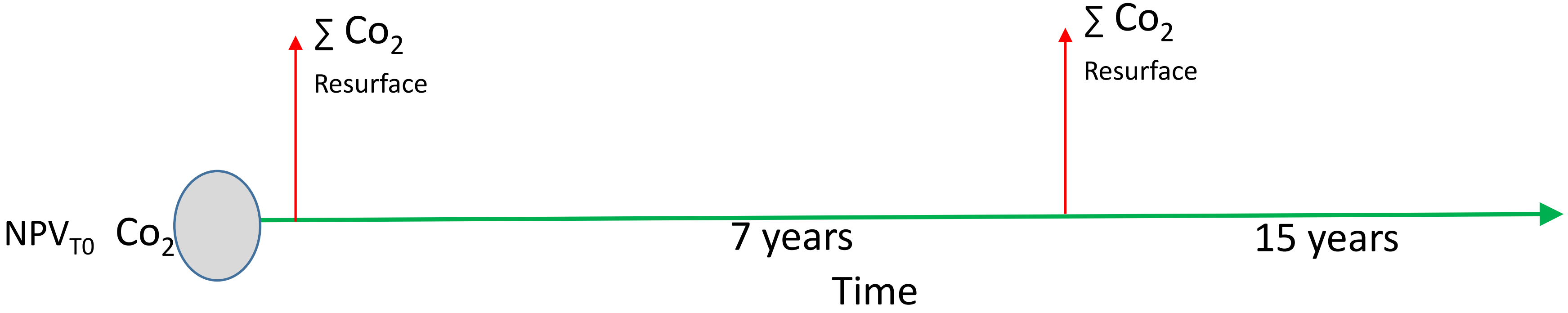
Technologies – Food For Thought

Crumbed Rubber

- Long service life
- High Stress/Loading Resilience
- Asset Management:
  - Long Service/ reduce risk
  - Sweat the Asset

Difficult to Quantify CO_2 and $:

- Reactive Maintenance benefits
- Hard Maintenance life



Technologies – Coming Soon

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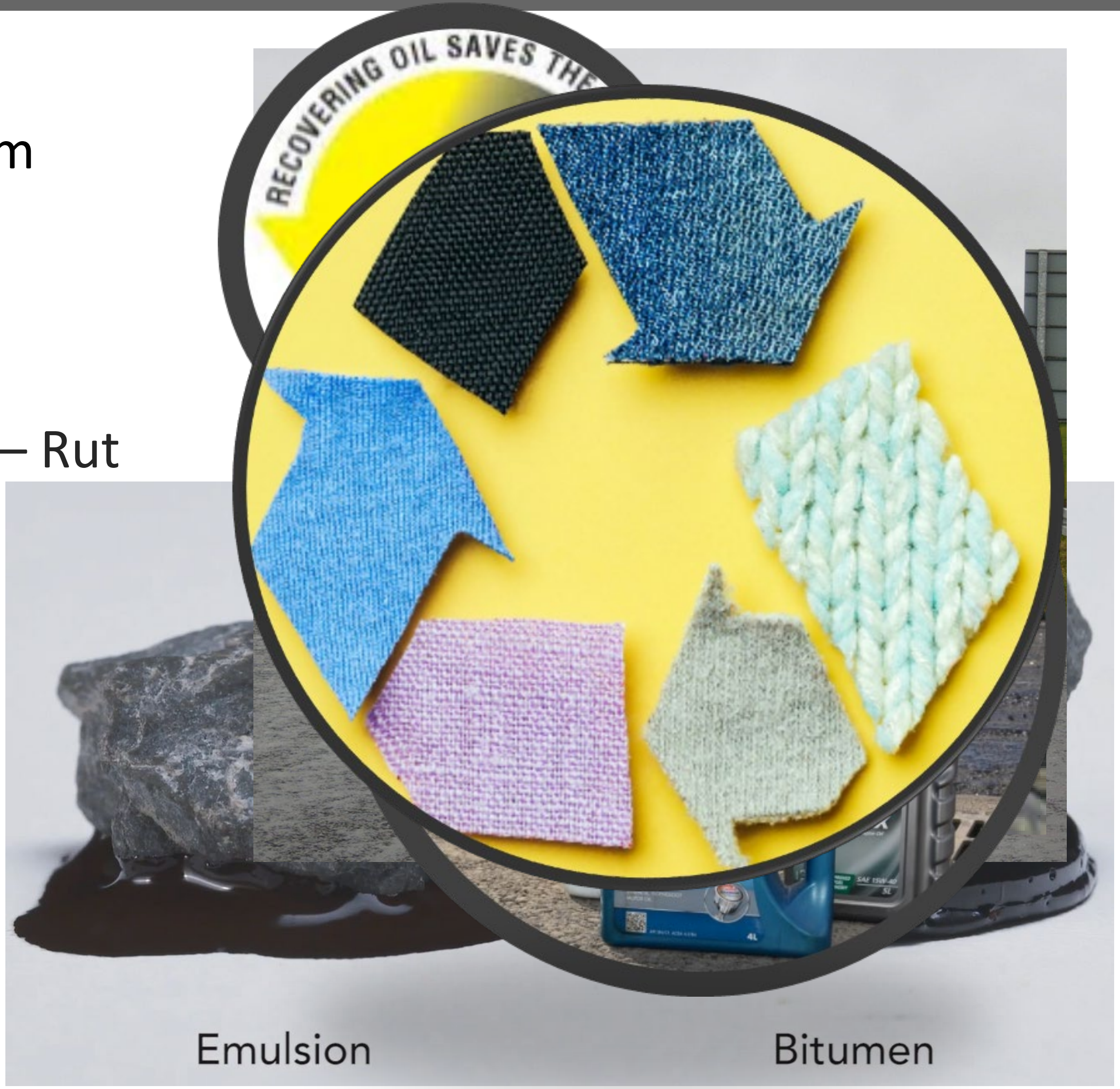
- Emulsion Chipseal – Meniscus ADVANTAGE
- Blended Cements – Lime Stone, Slag, Fly Ash, Gypsum
- Hot Rolled Asphalt - Slow Sharp Corner Alternative
  - SMA segregates Hauled > 250 km and Chipseal Flushes Annually
  - Texture depth of 1mm – 1.5 mm possible
- Dense Graded Granular Layers further development – Rut resistance improvement
- Crushed Glass Incorporation in Asphalt
  - Displace fines
  - Excess available
- Plastic/Bitumen blend Asphalt
- SMA – ~~Cellulose~~ Recycled Cloth
- Bitumen Replacement – Bio Bitumen (Trial 2017)



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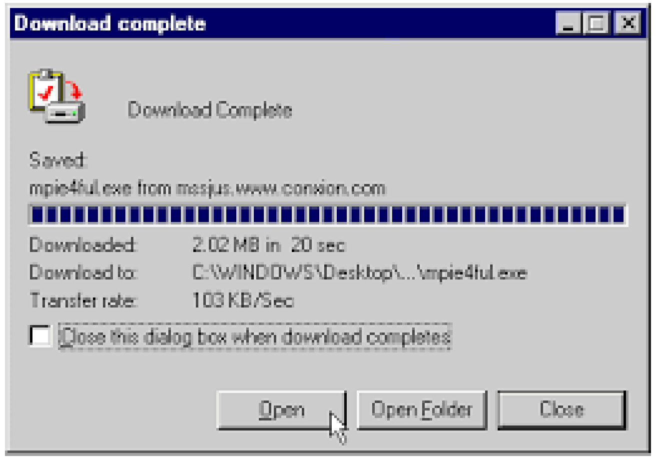
THANK YOU



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