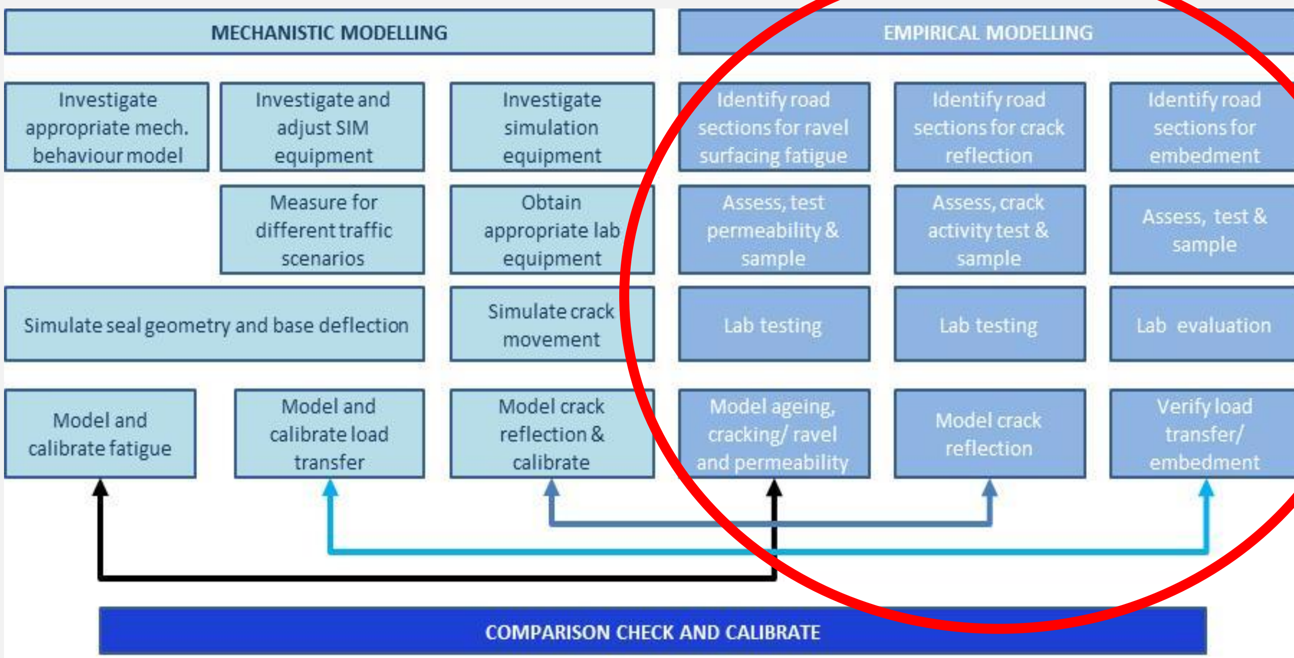
SEAL AGEING AND EFFECTS
RPF MAY 2014

THE SOUTH AFRICAN NATIONAL ROADS AGENCY LTD

MYCUBE ASSET MANAGEMENT SYSTEMS (PTY) LTD

Gerrie van Zyl

Empirical modelling



Model ageing, cracking/ ravel and permeability

Model crack reflection

Verify load transfer/ embedment

DATA SET 1
35 New Seal Sites

DATA SET 2
WCape Prov Gov (37)
HDM4 Calibration sections

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Focus of Presentation

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- Data sets
- Seal ageing
- Crack initiation
- Crack reflection

Data set 1: Matrix

- 70 **Samples**
  - 6 Surfacing types
    - Single seal
    - 13/6 Double
    - 19/9 Double
    - 19/6/6 Split
    - 13 Cape seal
    - 19 Cape seal
  - 2 Binder types
    - Conventional (80/100 and Cat 65)
    - Modified (SE-1)
  - 5 Macro Climatic areas
  - Traffic ranges
  - Age (2 – 24 years)

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Assessments recorded

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- **Detailed visual**
  - ❑ (10m – Shoulder, OWT, between and IWT)
- **Photographs of each defect type**
- **Texture measurement**
  - ❑ (Wheel track, outside wheel track)

MR00188 + 22.96 24.70 519 19mm Cape S 15 1996 Durbanville km 23.5 S33o43'26. E018o41'47.7 1 Paarl Boland to be res

		Surfaced Shoulder					Outer wheel track					Between wheel tracks					Inner wheel track				
		Croc pattern	Long C	Trans v C	Agg Loss	Fattin ess	Croc pattern	Long C	Transv C	Agg Loss	Fattines s	Croc pattern	Long C	Trans v C	Agg Loss	Fattin ess	Croc pattern	Long C	Trans v C	Agg Loss	Fattin ess
	10	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
	6	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	3	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0
23.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0		1	0

	SS	OWT	BWT	IWT
Texture	2.08	1.59		
Diam (m	175	200		

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Sampling

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- **Sampling**
  - ❑ Slabs & cores
  - ❑ In and outside wheel track



Testing

- **On site**
  - ❑ RSD
  - ❑ DCP
  - ❑ Rut
  - ❑ Texture depth

- **Laboratory**
  - ❑ Binder (Softening point/ penetration)
  - ❑ Permeability (Marvil & core)

Results

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Age-hardening

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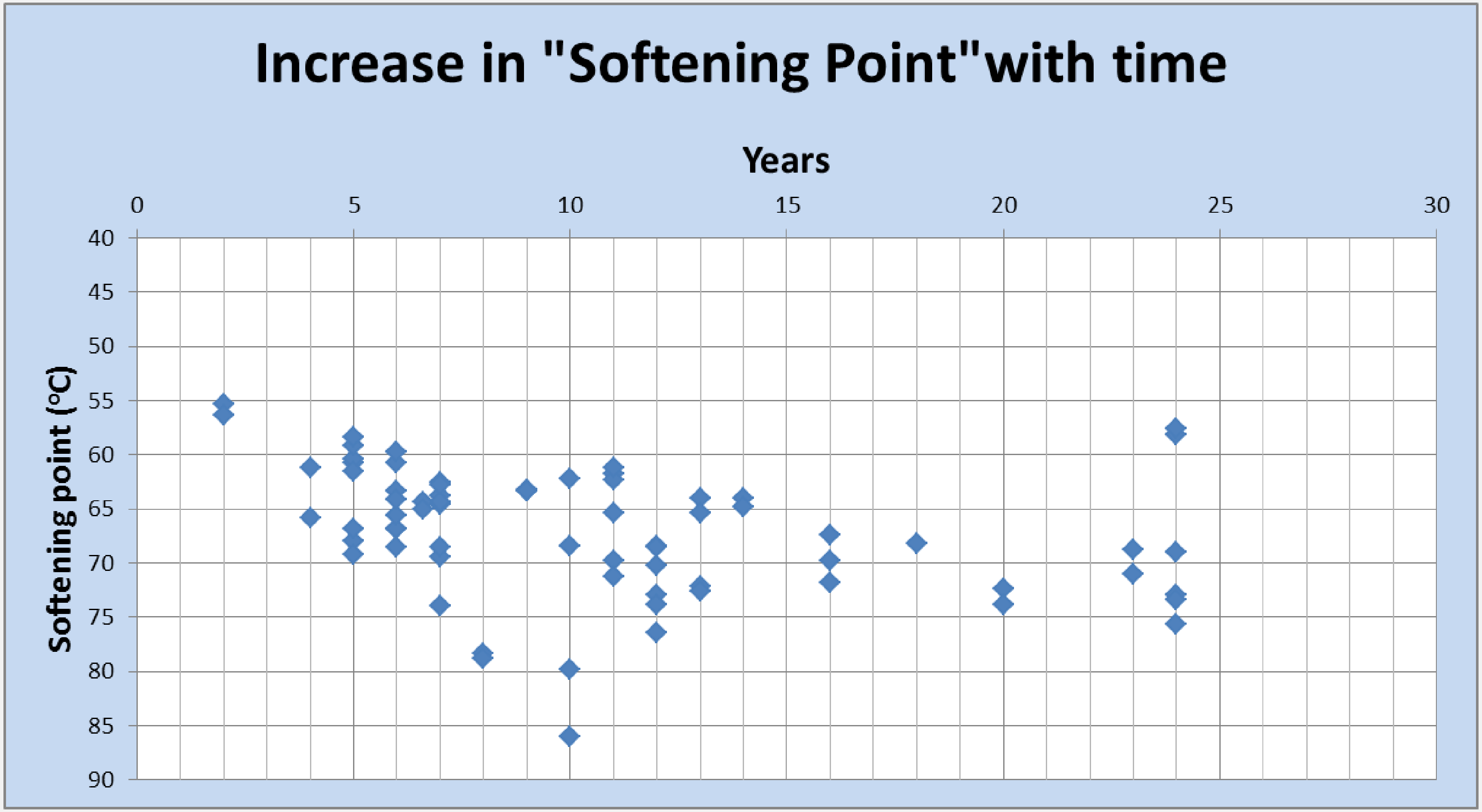
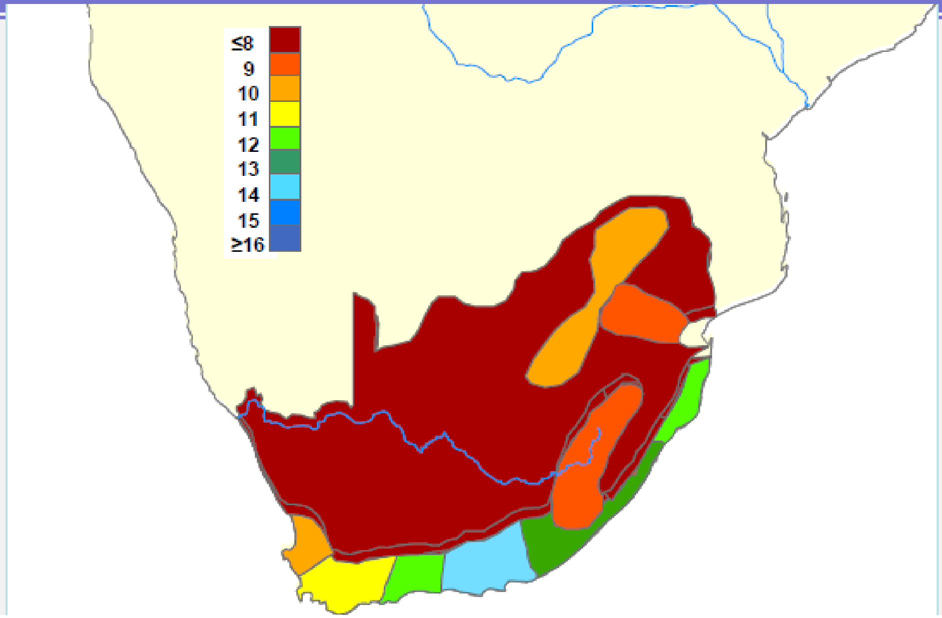


John Oliver model applied



$$\log \eta = .0498\, T\, Y^{0.5} - .0216\, D\, Y^{0.5} - .000381\, S^2\, Y^{0.5} + 3.65 \quad (1)$$

Where :

η = the viscosity of bitumen recovered from the sprayed seal (Pa.s at 45ºC and $5 \times 10^{-3}\ s^{-1}$),

T = the average temperature of the site (ºC), calculated from equation (2),

D = the ARRB Durability Test result (days),

S = nominal seal size (mm),

Y = the number of years since the seal was constructed,

$$T = (TMAX + TMIN)/2 \quad (2)$$

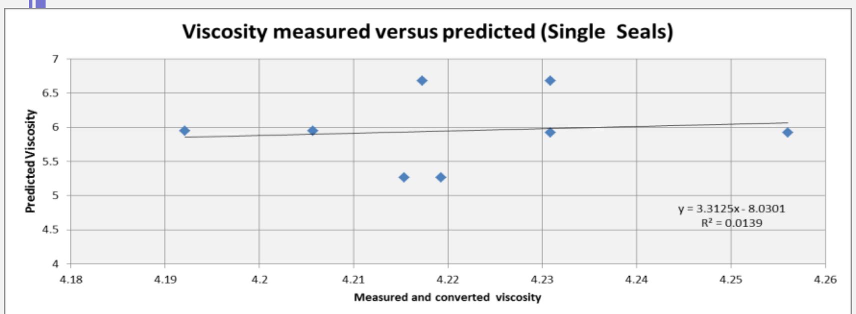
where

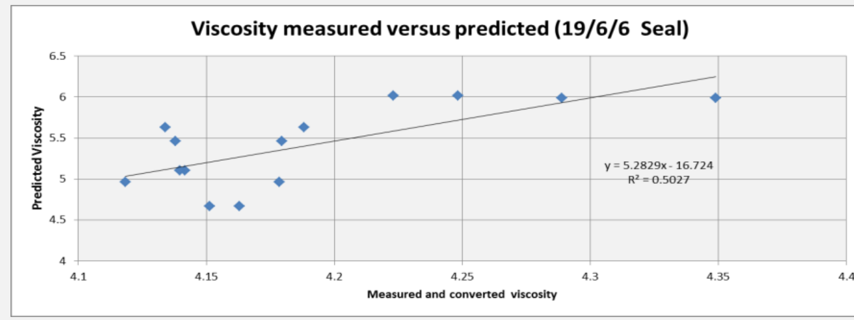
$TMAX$ = the yearly mean of the daily maximum air temperature (ºC), and

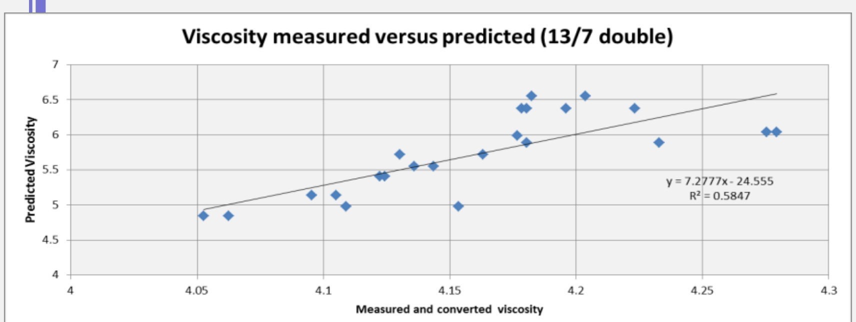
$TMIN$ = the yearly mean of the daily minimum air temperature (ºC).

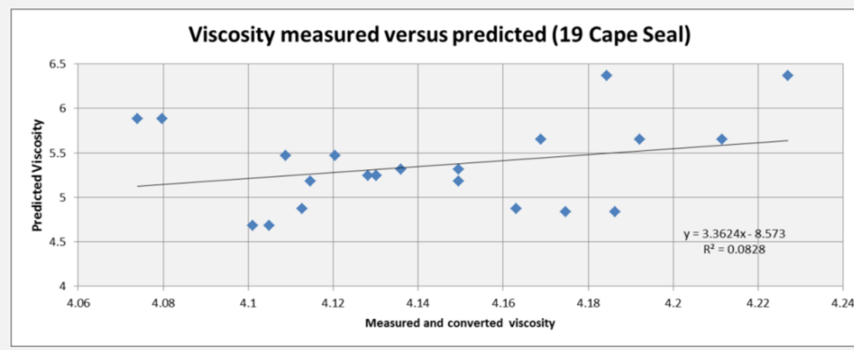
Ageing

- Poor correlation with mean annual temperature
- Oliver models



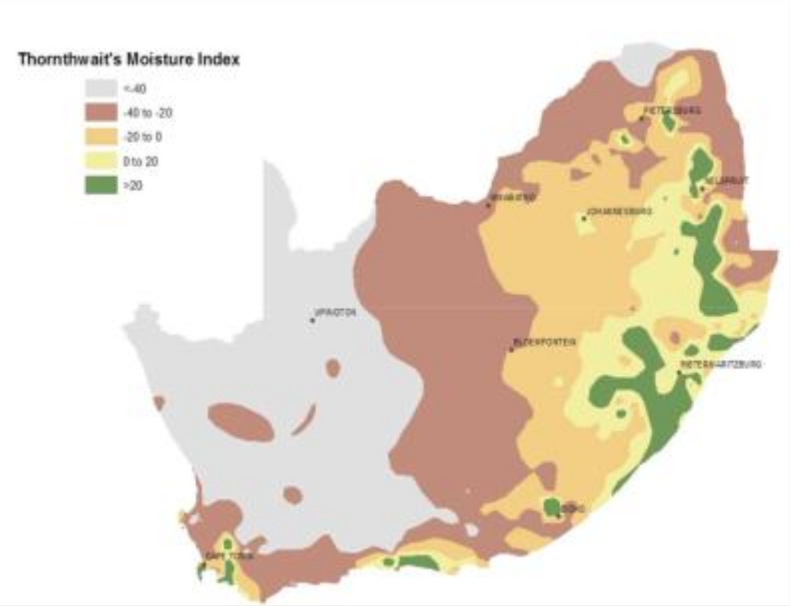






Ageing

- **Tested different macro climatic systems**
- **Most logical results with Thorthwaite MI**



Hardening: Double seals

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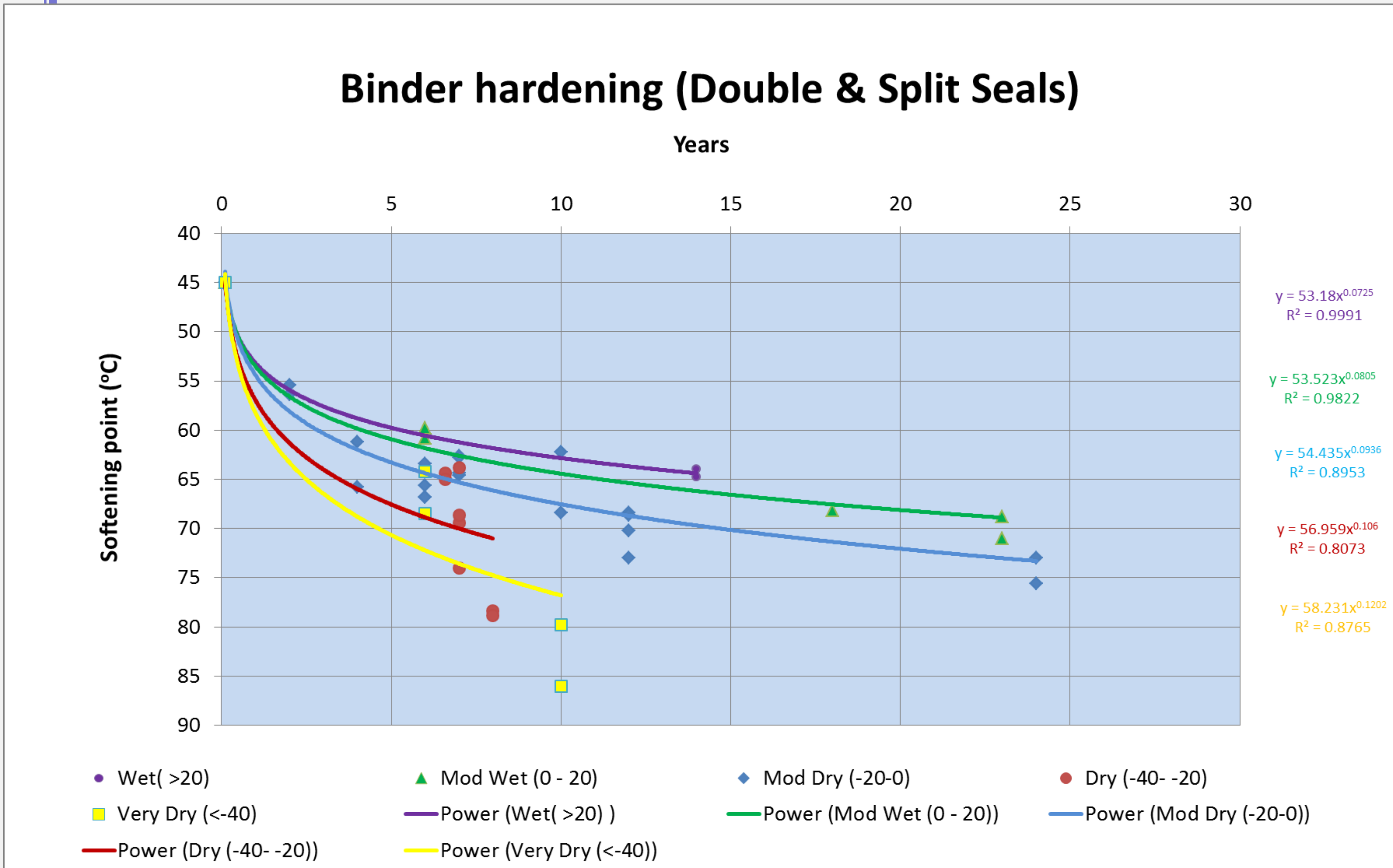
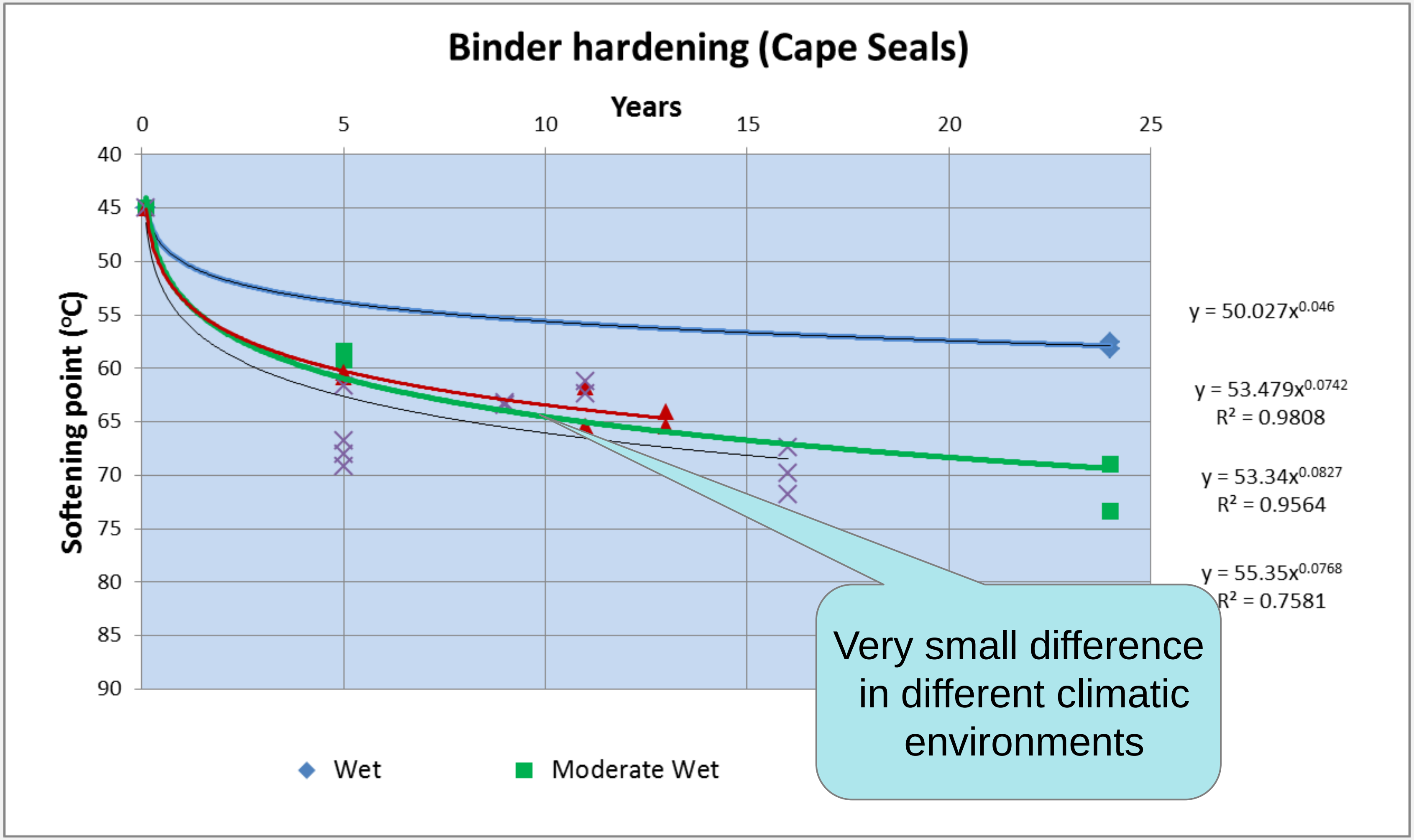
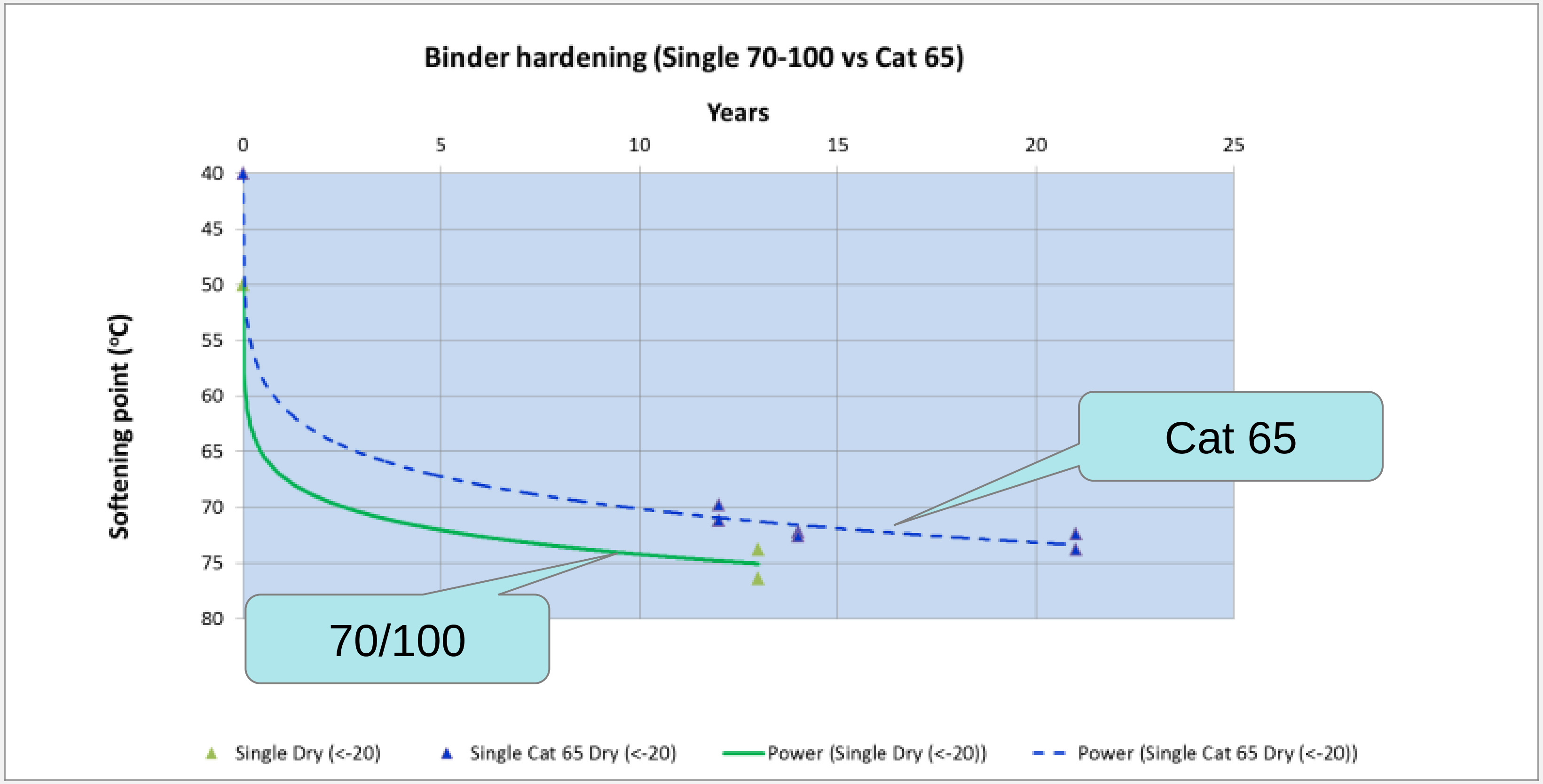


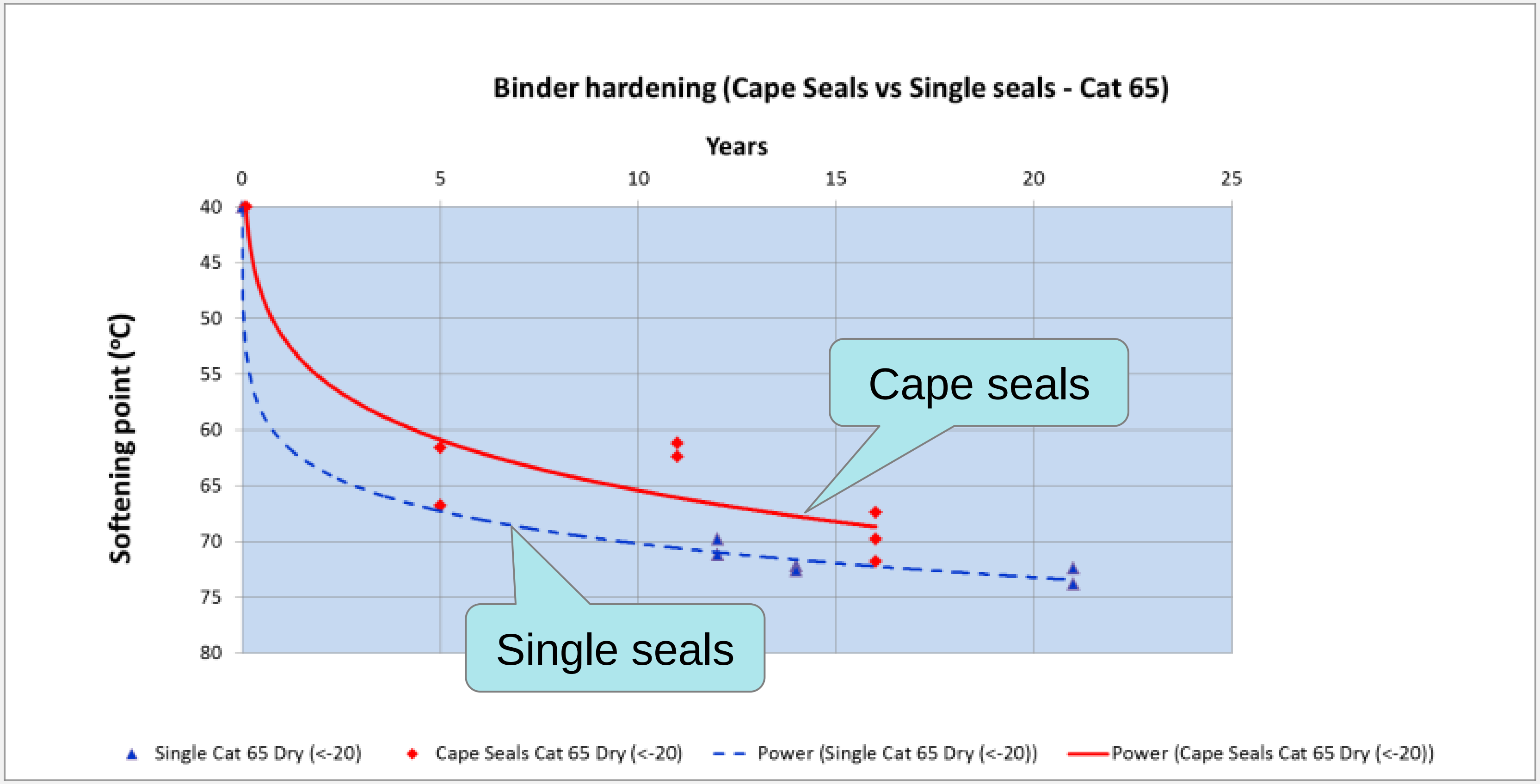
Hardening: Cape Seals



Effect of binder type on hardening



Hardening: Cape seals vs Single Seals



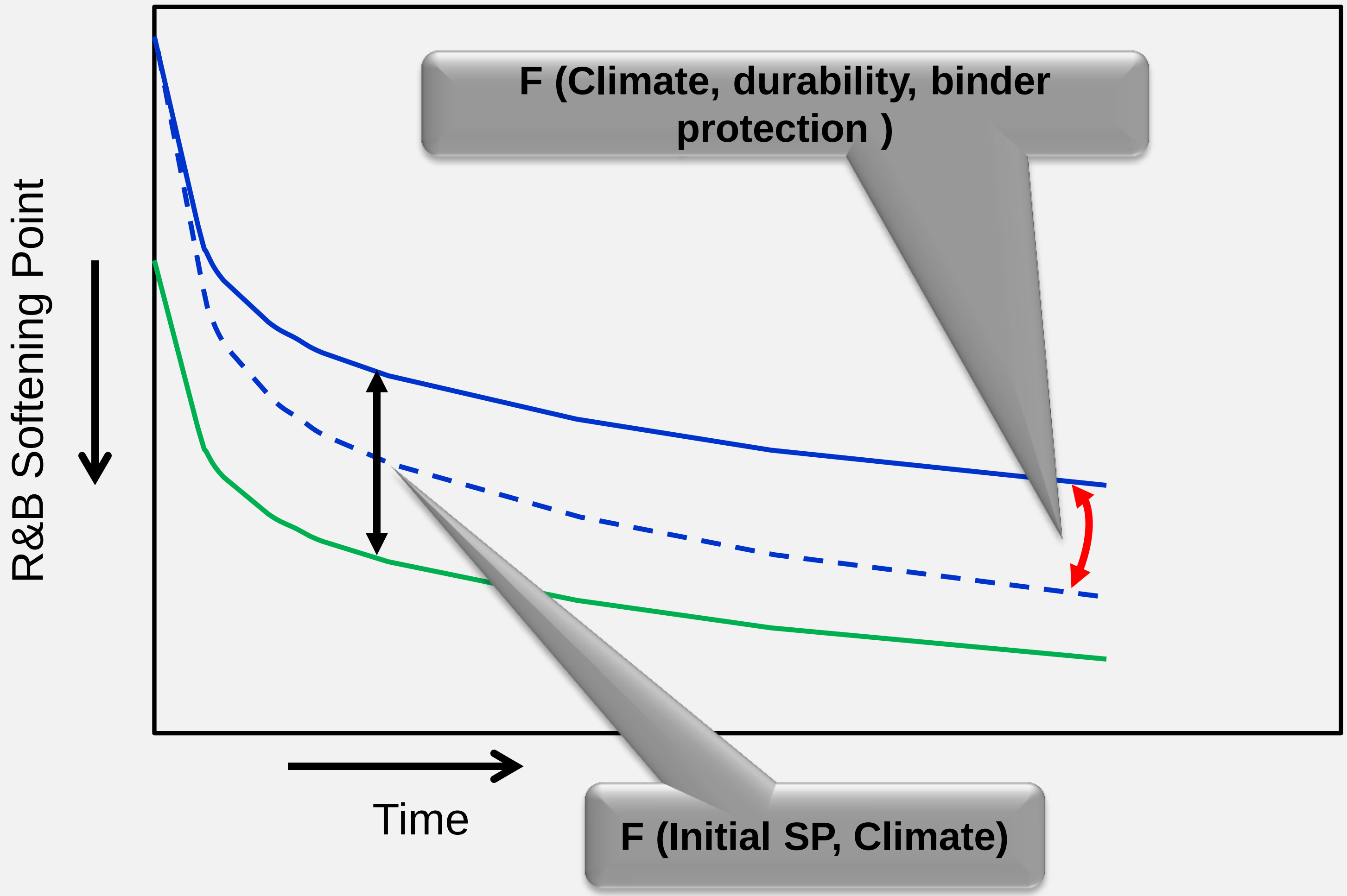
Hardening: In- out of wheel tracks

Seal type	Higher Softening Point outside Wheel Track	Higher Softening Point in Wheel Track	Total number of roads tested
Cape Seal Seals	8	4	12
Double Seals	7	5	12
Split Seals	1	6	7
Single seals	1	3	4
	17	18	35

Binder hardening Conclusions

- **Function of**
  - Binder type/ quality
  - Seal type (Thickness/ structure)
  - Time
  - Climate
- **Model form**

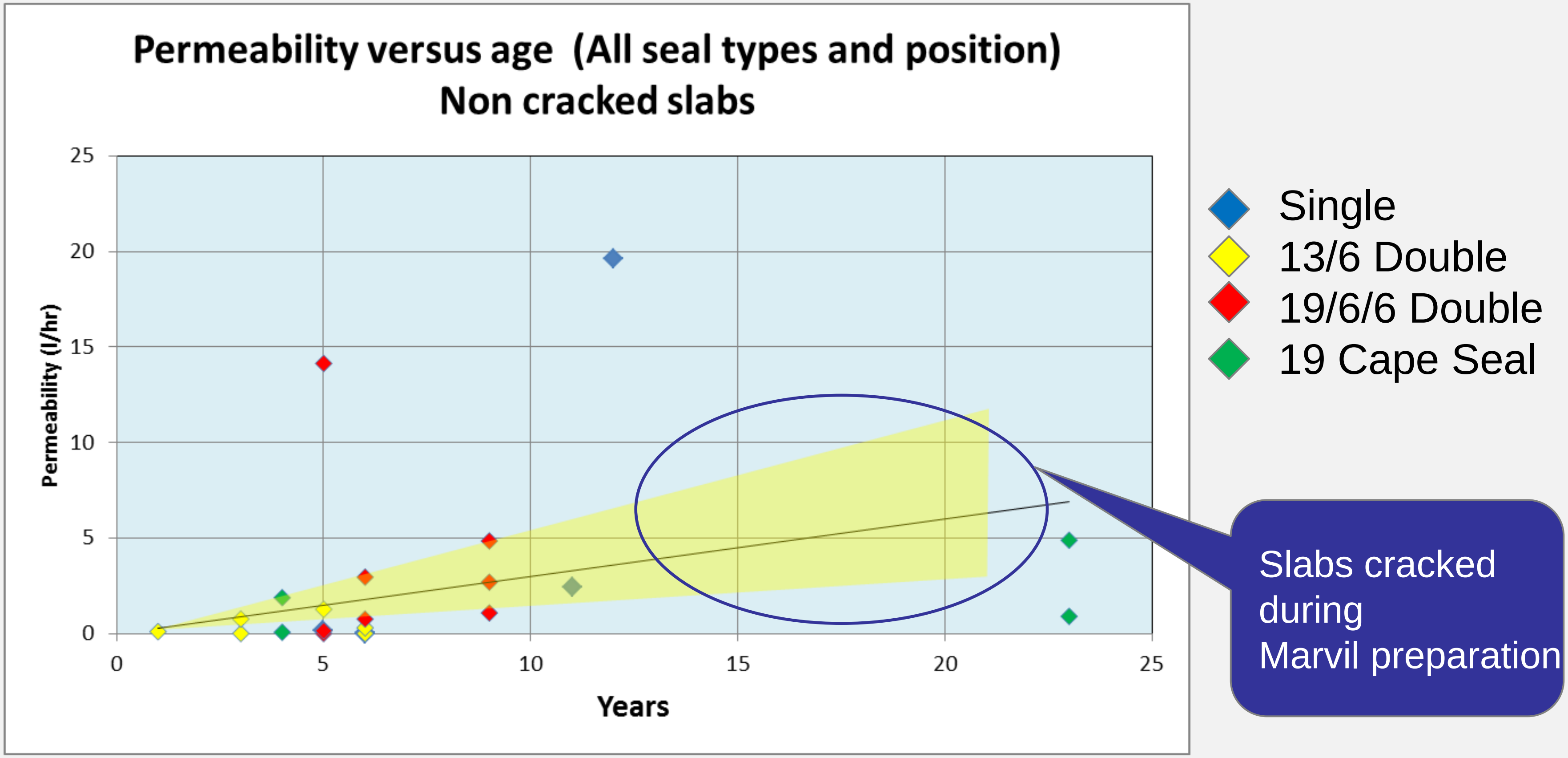
$$F(t)=1-e^{-\left(\frac{t}{\alpha}\right)^{\beta}}$$



F (Climate, durability, binder protection)
R&B Softening Point
Time
F (Initial SP, Climate)

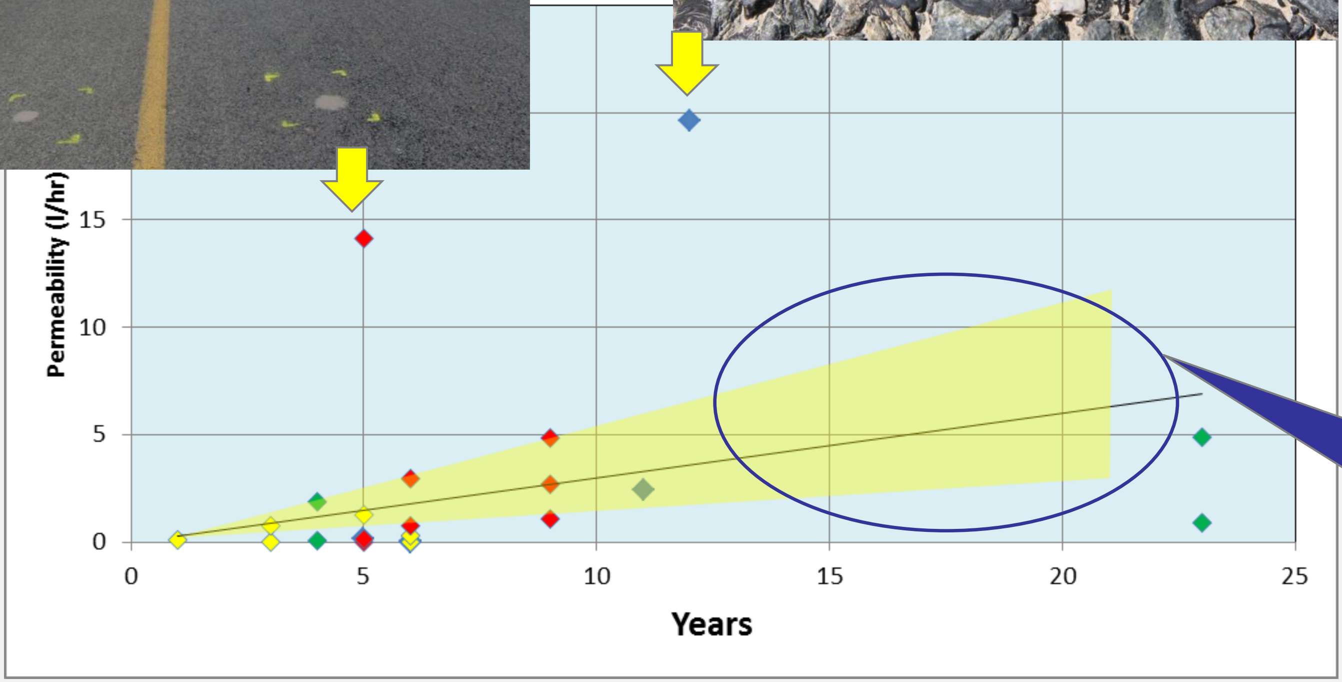
Marvil Permeability

- Only proportion through to base
- Increase in permeability with time



Marvil Permeability (Outliers)

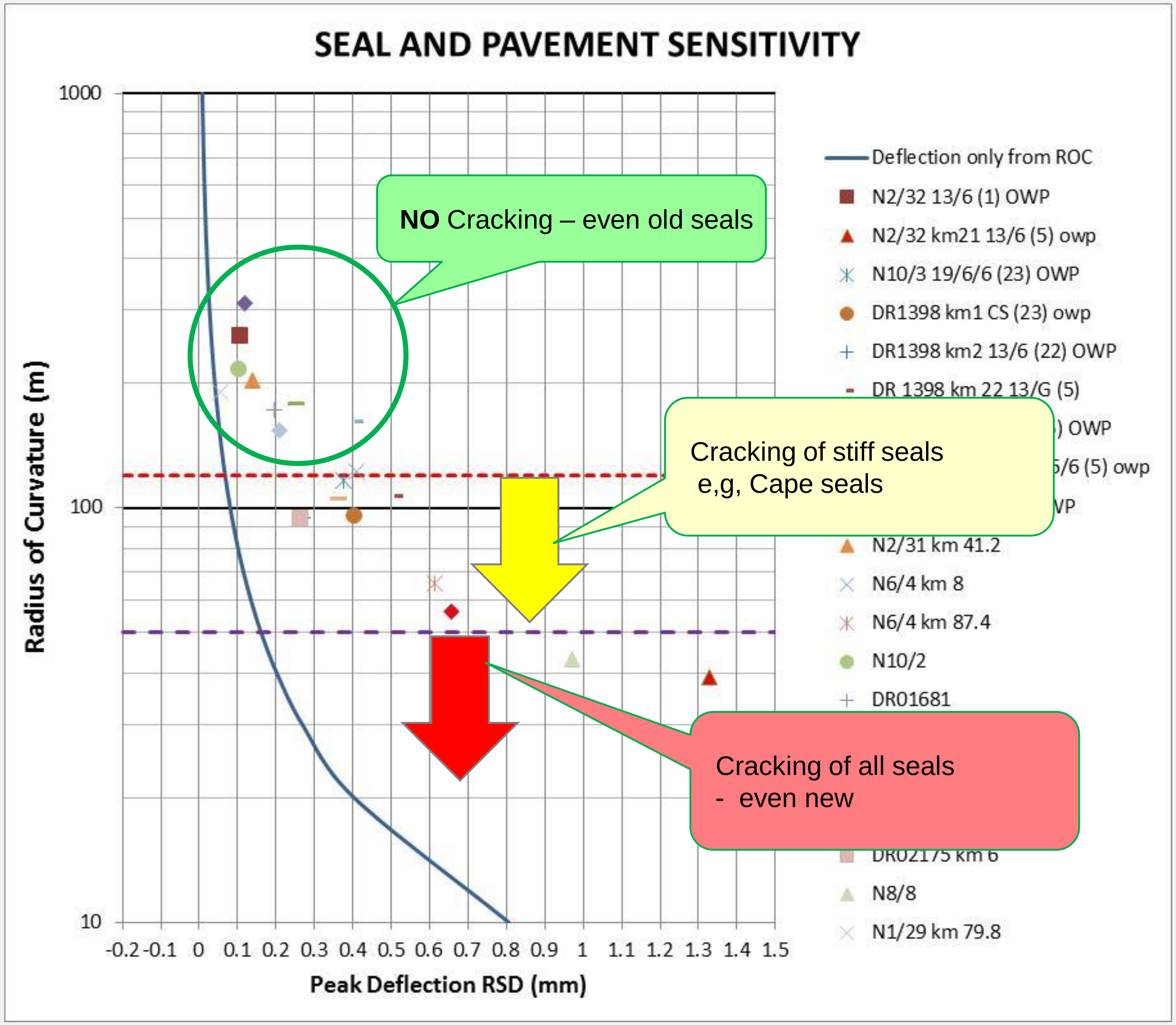
- Only proportion t



Single
13/6 Double
19/6/6 Double
19 Cape Seal

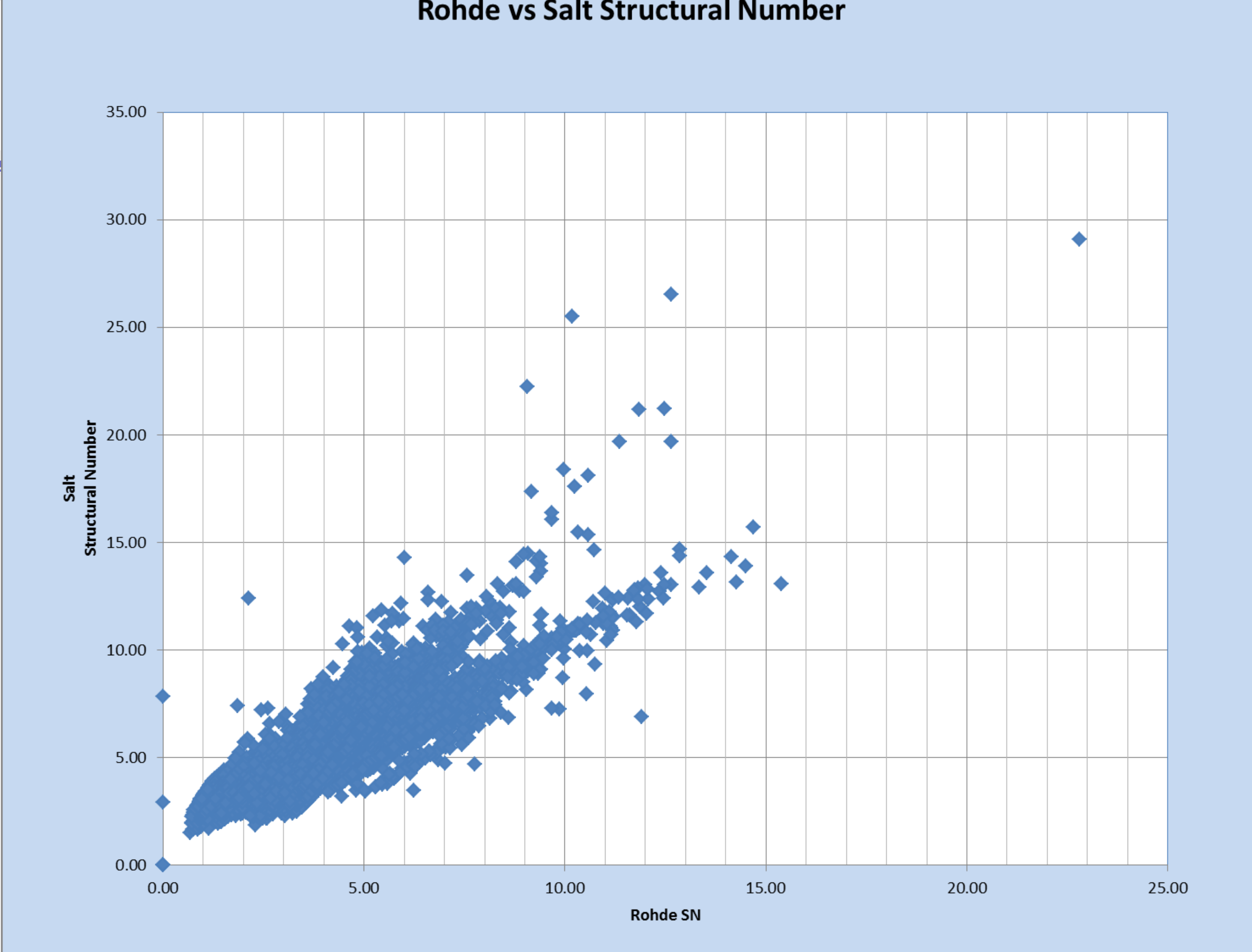
Slabs cracked during Marvil preparation

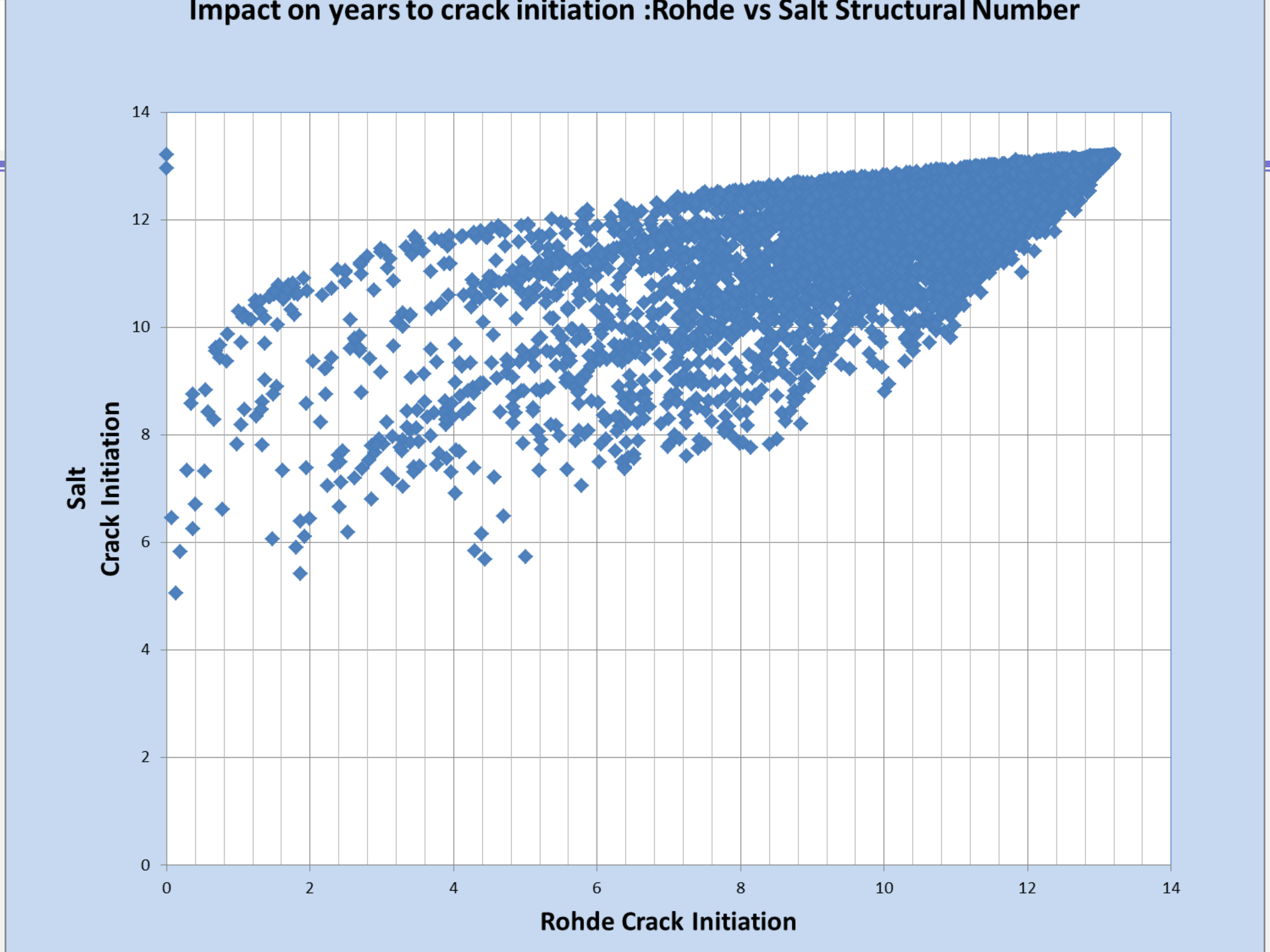
Cracking: Initial findings



Crack initiation

- Impact of Structural number calculation
- HDM4 prediction


Rohde vs Salt Structural Number
Salt
Structural Number
Rohde SN
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
5.00
10.00
15.00
20.00
25.00


Impact on years to crack initiation :Rohde vs Salt Structural Number
Salt
Crack Initiation
Rohde Crack Initiation
0
2
4
6
8
10
12
14

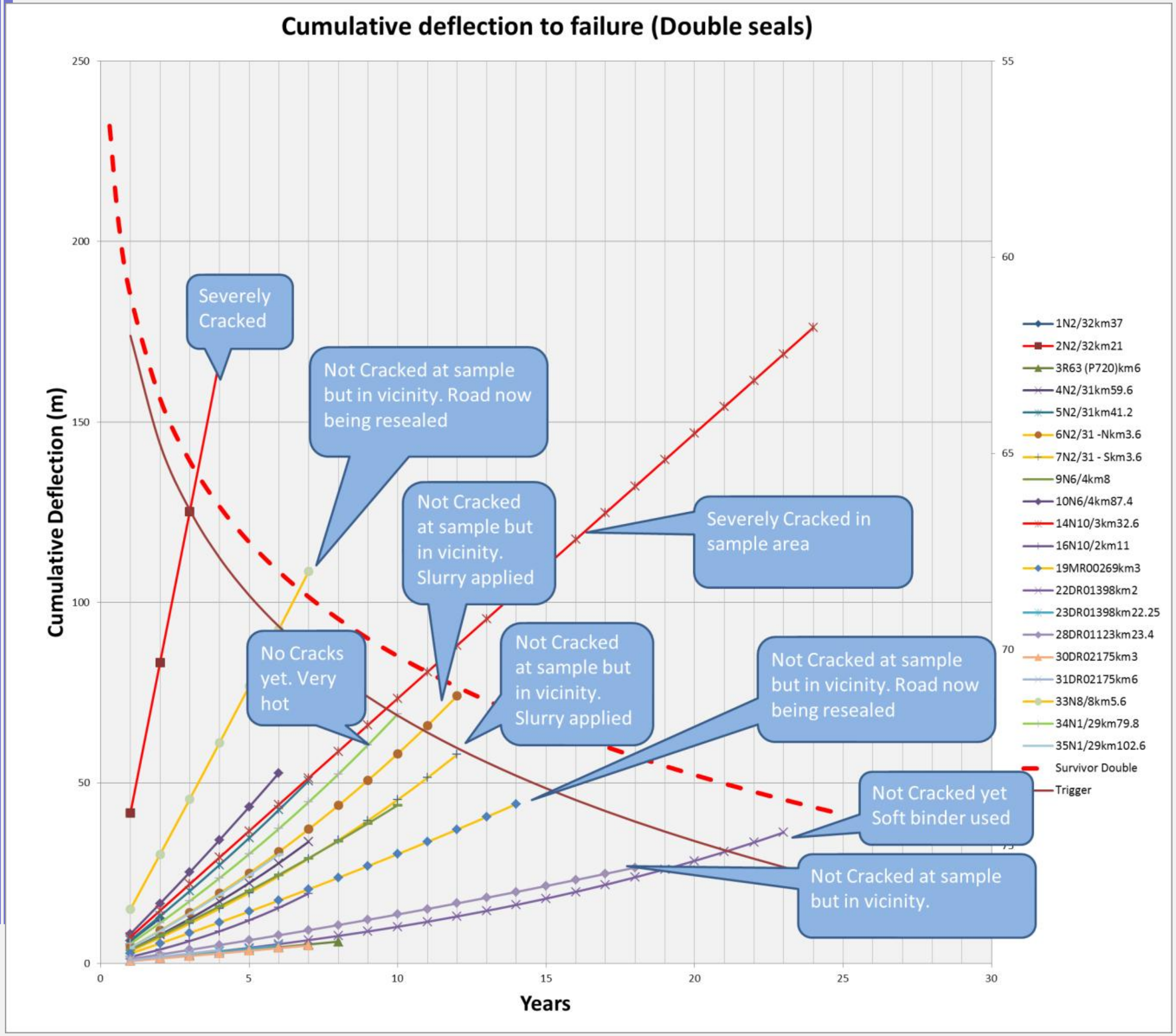
Crack initiation

- **Development of survivor curves**
- **Function of**
  - Cumulative deflection (strain)
  - (d127 –d0 x 80kN axles) provided logical results
  - Seal stiffness
  - Operating climate
- **Model form**

$$ICA = K_{cia}\{CDS^2\, a_0 \exp[a_1 SNP + a_2(YE4/SNP^2)] + CRT\}$$

$$F(t) = 1 - e^{-\left(\frac{t}{\alpha}\right)^{\beta}}$$

Survivor curve: Double seals



Survivor curve: Cape seals

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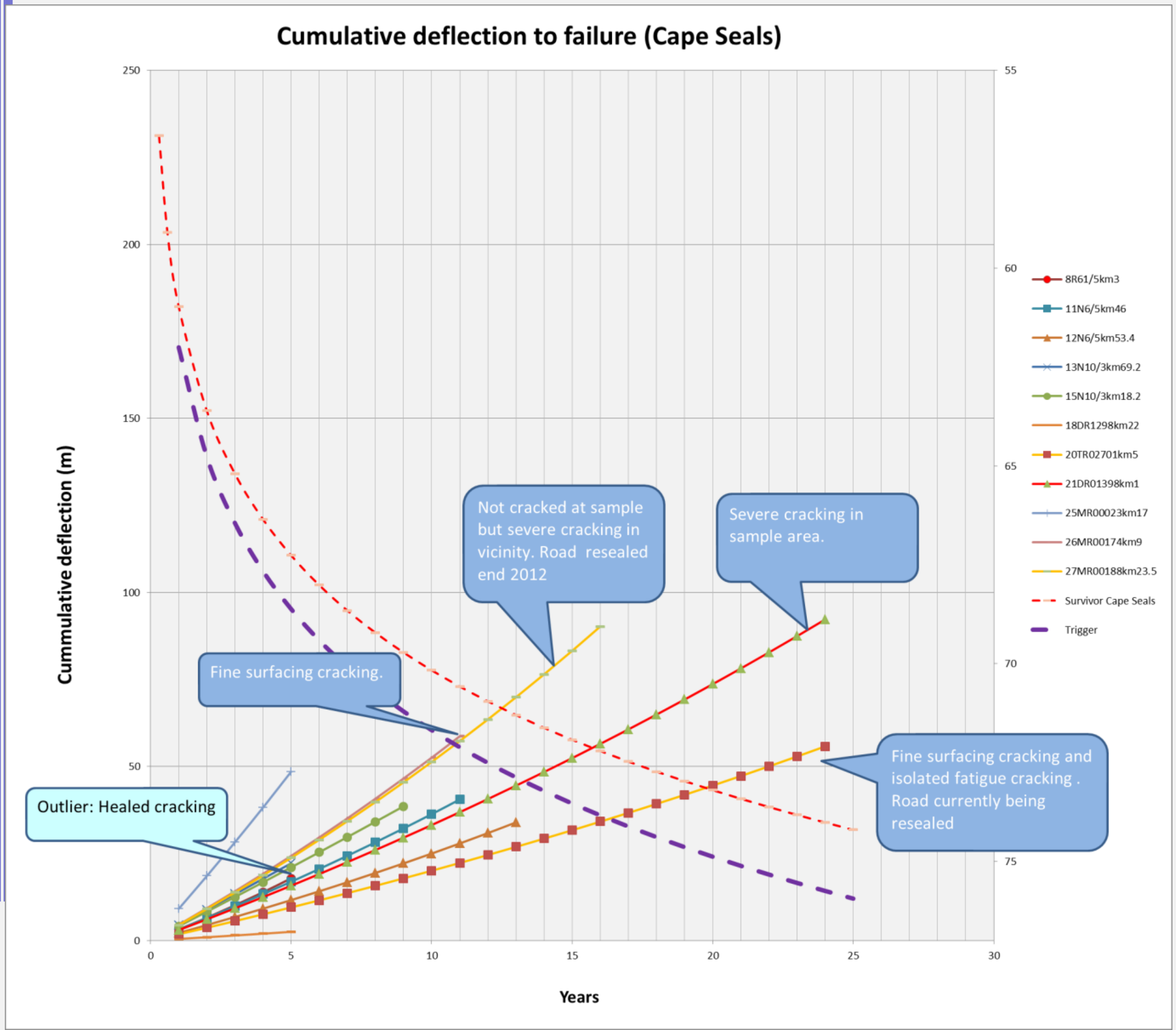

Age-hardening vs Cracking

- **Also dependent on:**
  - ❑ Seal geometry
  - ❑ Binder characteristics
  - ❑ Operational temperature
- **Integration**
  - ❑ 4-Point beam tests (Stiffness & fatigue characteristics) – R Cloete
  - ❑ DSR on age binders (E Mukundila)

Quantifying Stiffness & Fatigue characteristics

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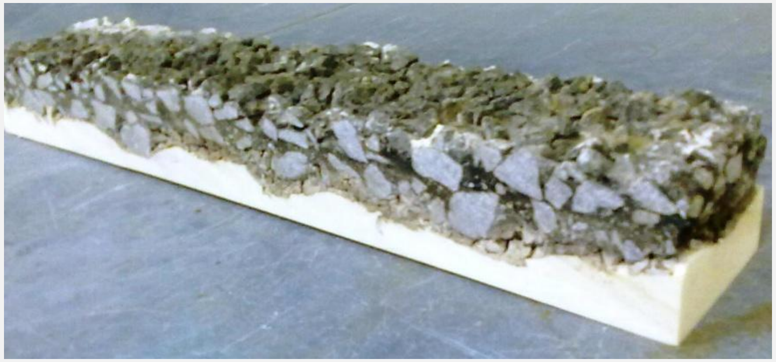
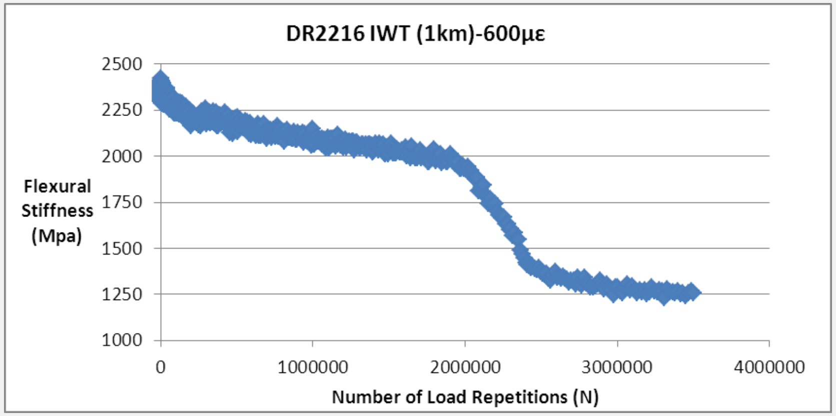
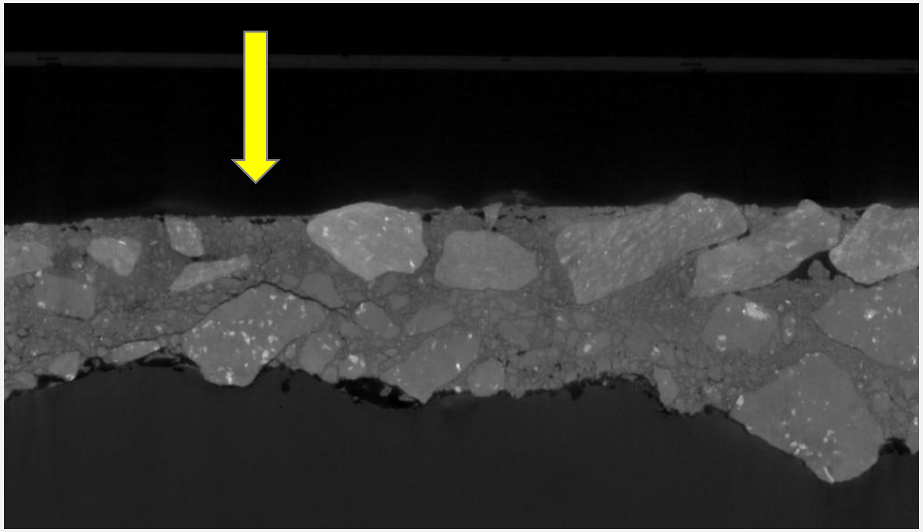
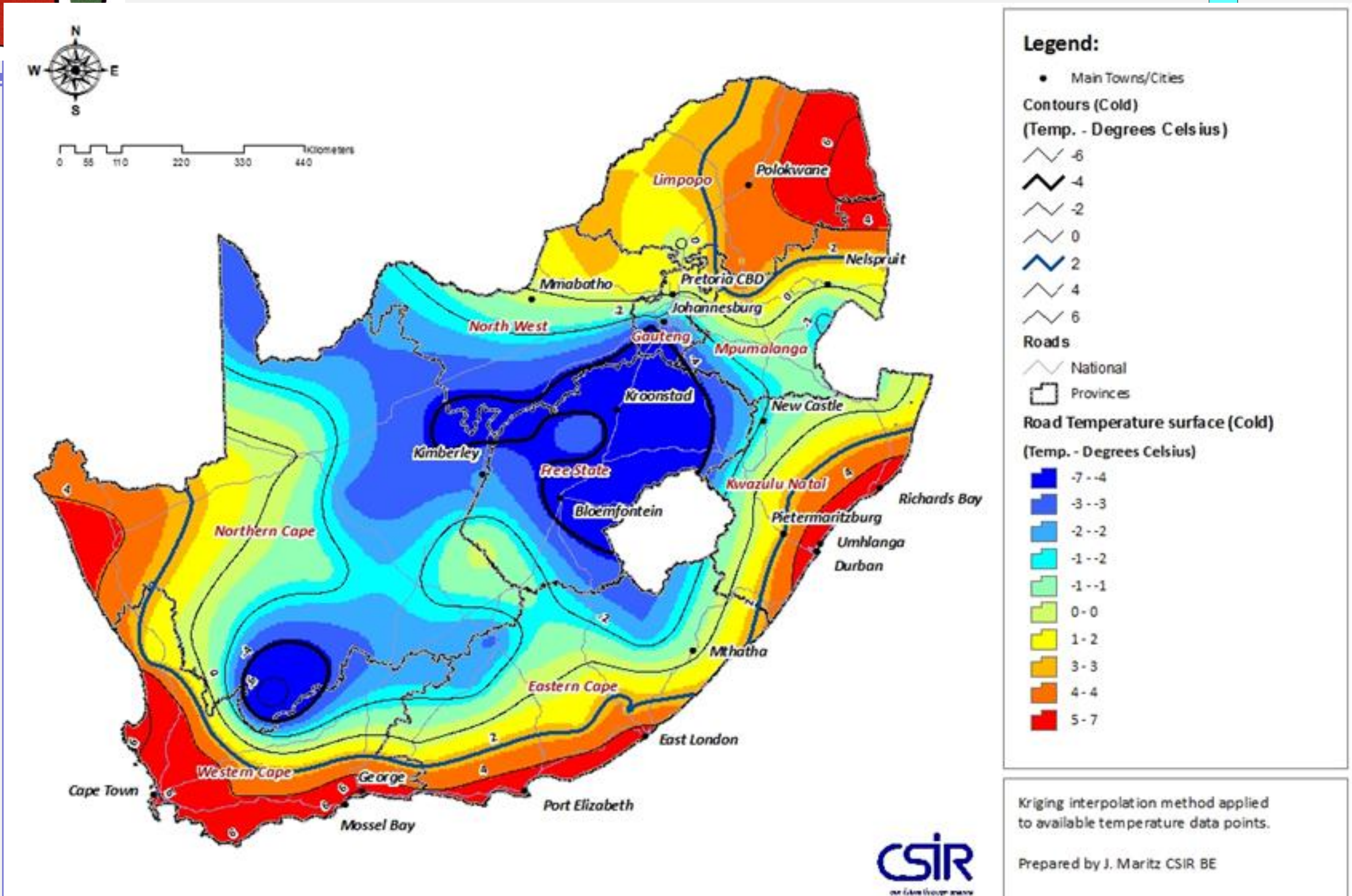
- Romei Cloete (M Student)





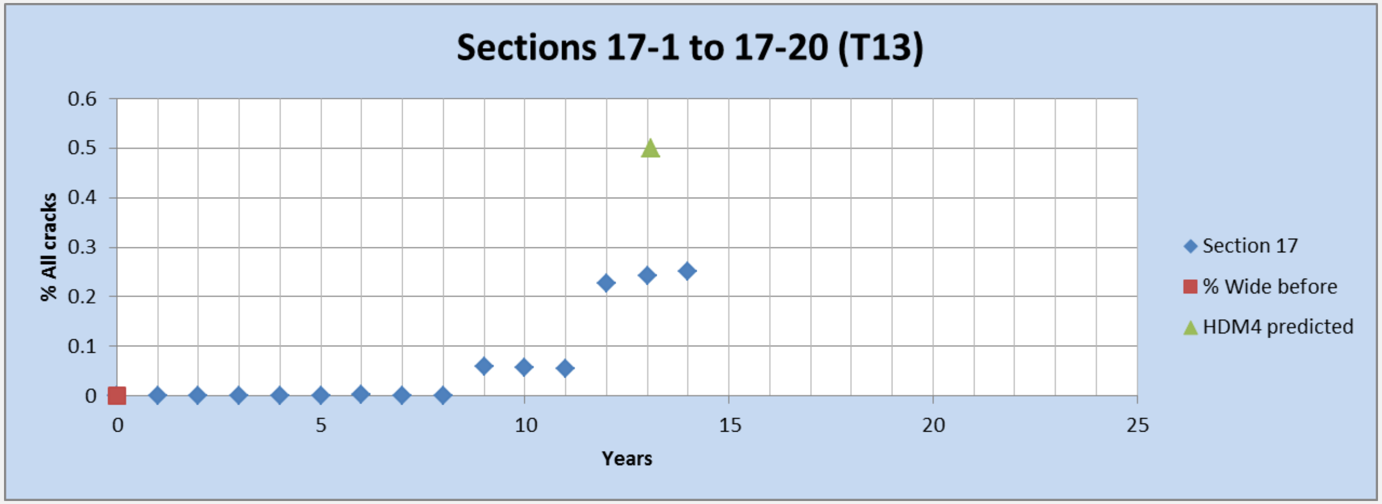


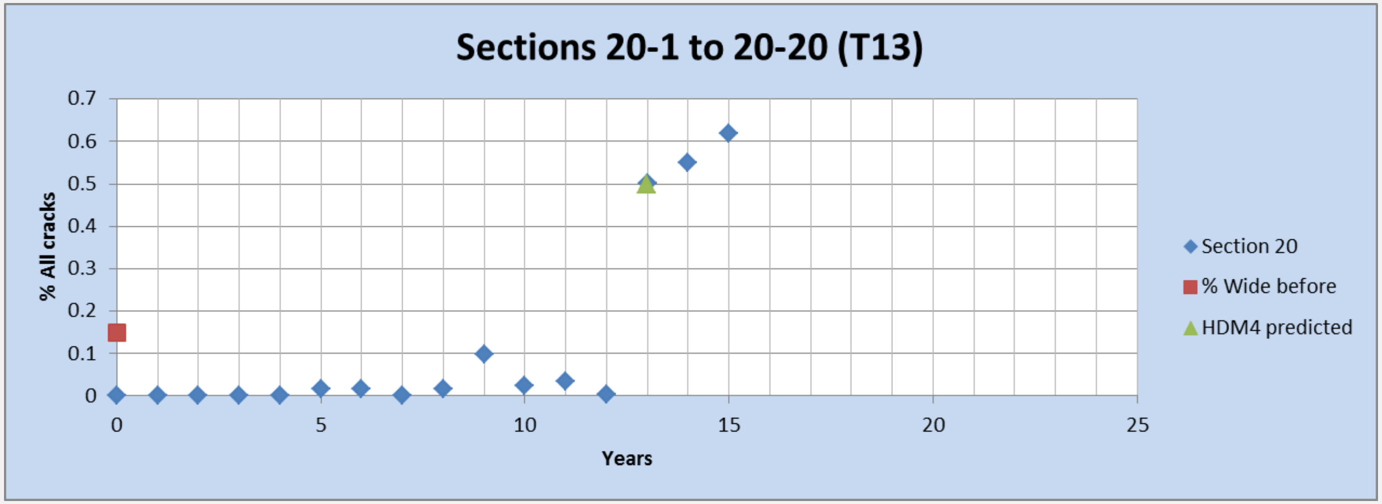

N
W
E
S
Kilometers
0 55 110 220 330 440
Limpopo
Polokwane
Nelspruit
Mmabatho
Pretoria CBD
Johannesburg
North West
Gauteng
Mpumalanga
Kroonstad
New Castle
Kimberley
Free State
Kwazulu Natal
Richards Bay
Bloemfontein
Pietermaritzburg
Northern Cape
Umhlanga
Durban
Mthatha
Eastern Cape
East London
Western Cape
George
Cape Town
Port Elizabeth
Mossel Bay
Legend:
Main Towns/Cities
Contours (Cold)
(Temp. - Degrees Celsius)
-6
-4
-2
0
2
4
6
Roads
National
Provinces
Road Temperature surface (Cold)
(Temp. - Degrees Celsius)
-7 - -4
-3 - -3
-2 - -2
-1 - -2
-1 - -1
0 - 0
1 - 2
3 - 3
4 - 4
5 - 7
Kriging interpolation method applied to available temperature data points.
Prepared by J. Maritz CSIR BE
CSIR

Crack reflection

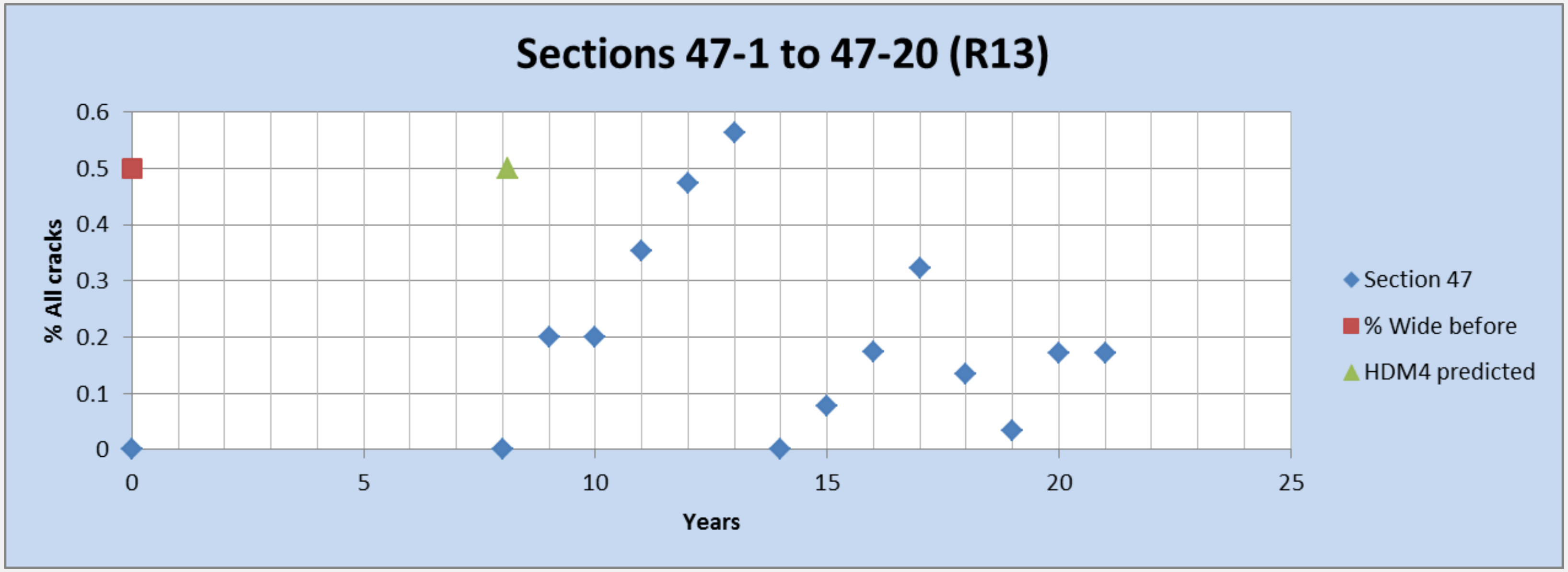
- Data set 2: WCPA calibration sections
- 34 x 20 road sections
- Comparison of HDM4 predicted versus measured
- Results (Function of film thickness and binder)

Example:T13 Predicted vs Measured





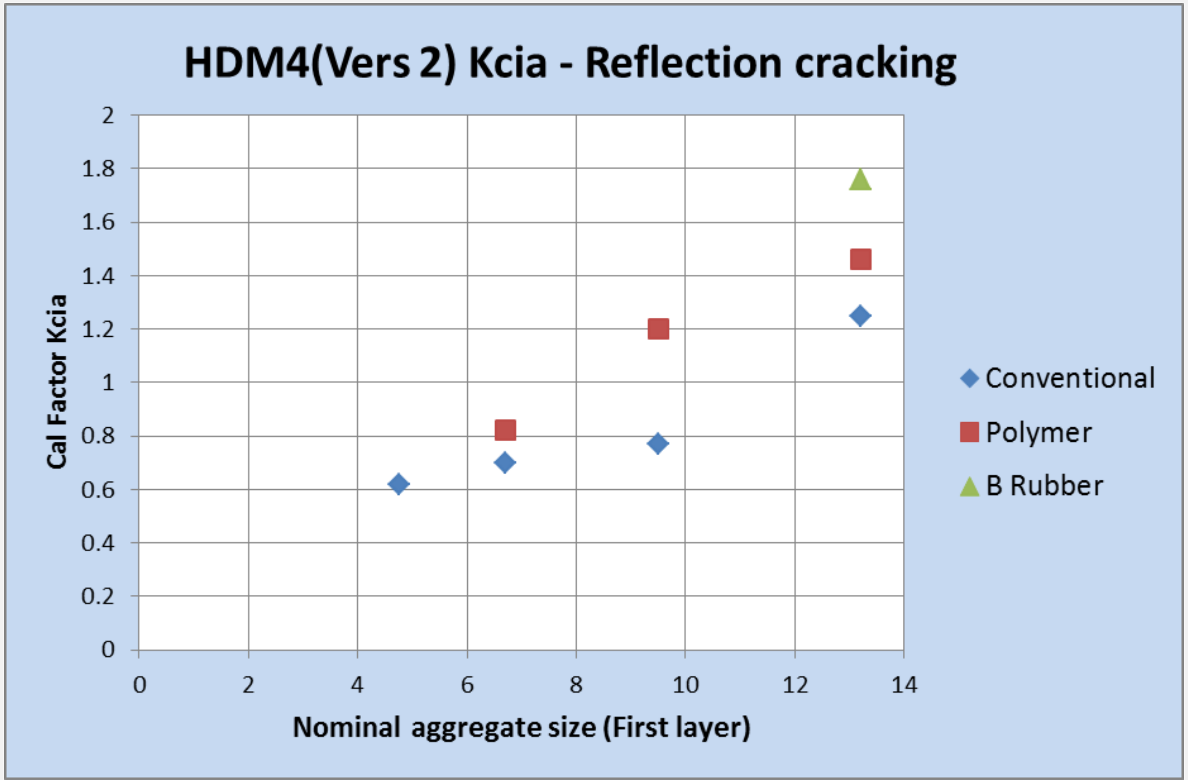
Example: R13



Sections 47-1 to 47-20 (R13)
% All cracks
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
Years
Section 47
% Wide before
HDM4 predicted

Crack reflection

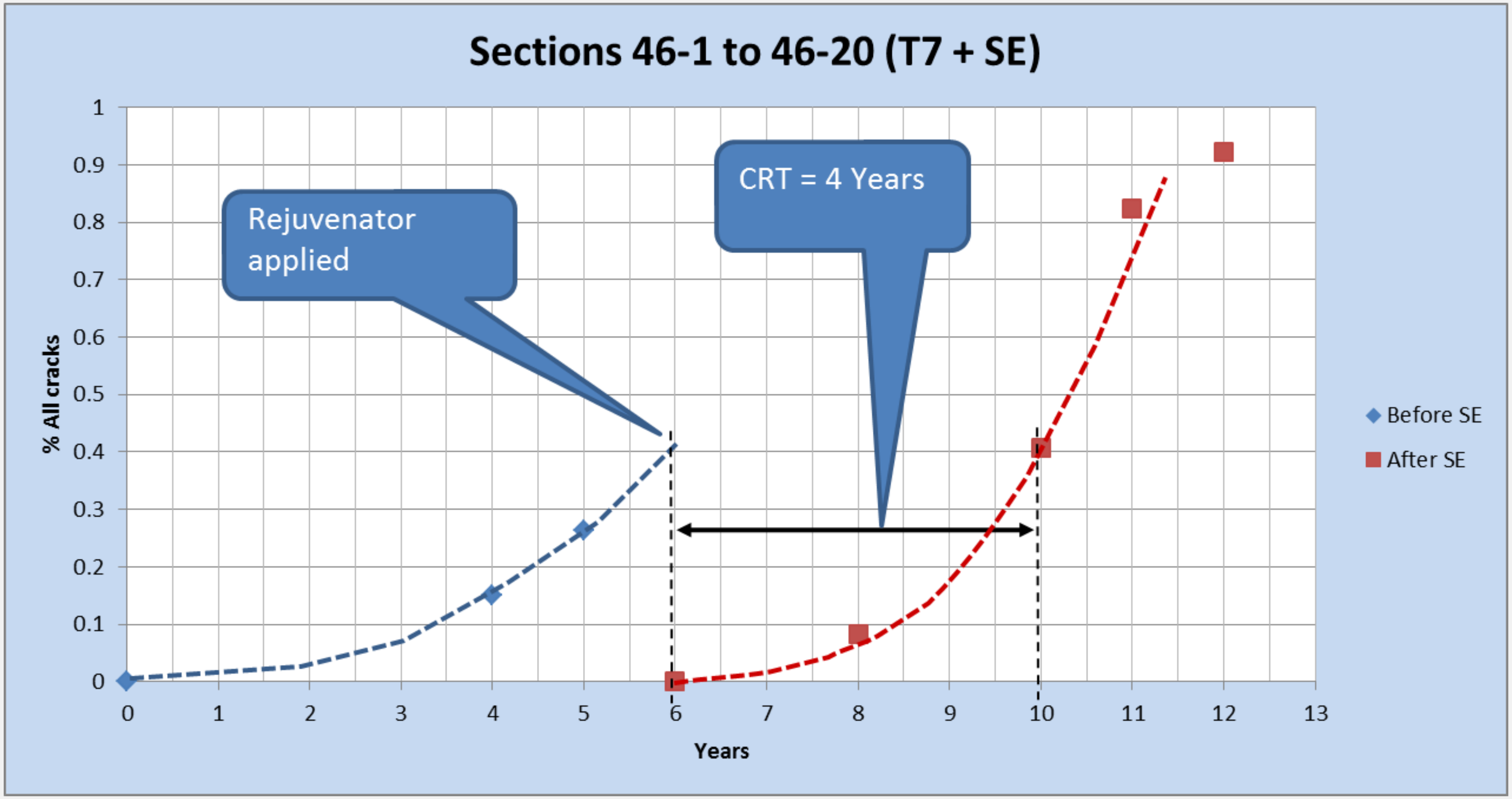
- **Results of 600 road sections**
- **HDM Calibration Factor = Measured/ Predicted**
- **Confirms effects of**
  - ❑ Film thickness
  - ❑ Binder type



Crack retardation

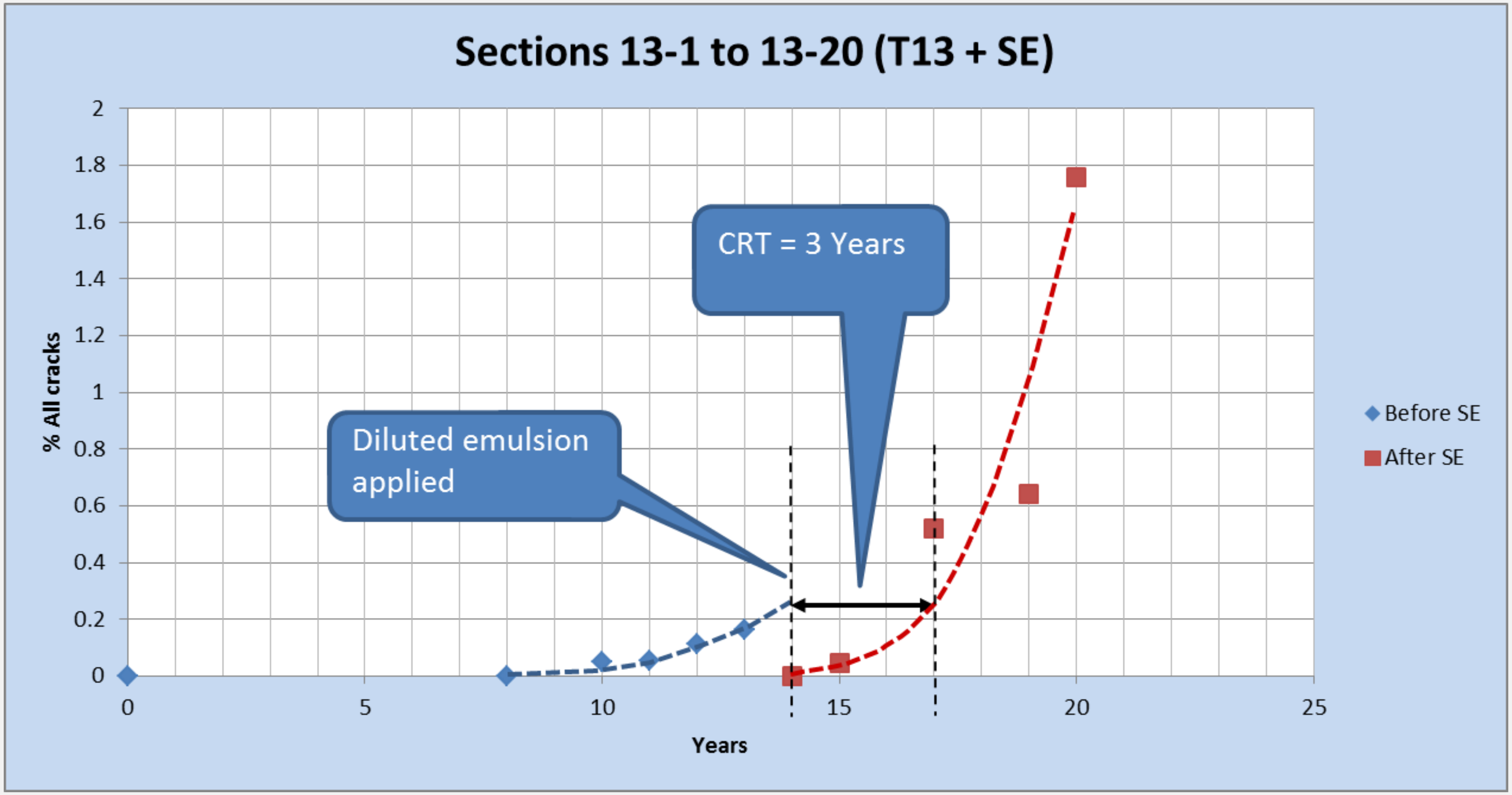
- **HDM4 CRT**
  - Fogsprays
  - Rejuvenation
- **Results**
  - 3 -4 years

Crack retardation due to rejuvenator



- **Note: Practical limitations**

Crack retardation due to Diluted emulsion



End

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