

# **Junkyard planet - opportunities for the re-use of builders rubble**

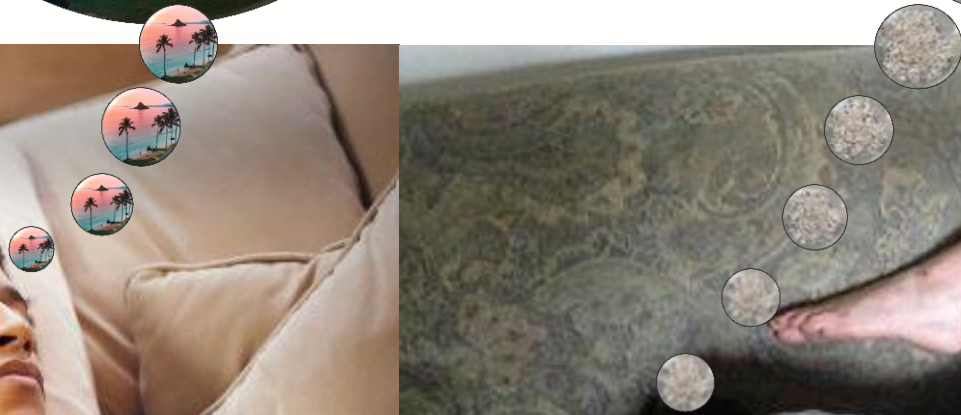
**Chantal Rudman**

**(Agnello, Beardmore, Cleghorn, Bredenkamp, Goosen, Kotze, Nel, Semugaza, Tawine, Tredoux)**

**Department of Civil Engineering**









**“Waste is the evidence we are doing something *wrong*.”**

**Landfilling means we are *burying* the evidence.**

**Incineration means we are *burning* the evidence”**



## Waste crisis in South Africa

### Legal landfills are few and far between.....

- 98 000 000 tonnes of waste generated
- 600 000 tonnes recycled
- Statistics show it takes **> 5 years** ( +1 year to build) if no public interventions. Currently **10 years**
- **Example: CoCT waste disposal currently spending 70% of their budget on operations**

## Waste crisis in South Africa

**Around 20-30% of landfill sites are builders' rubble**

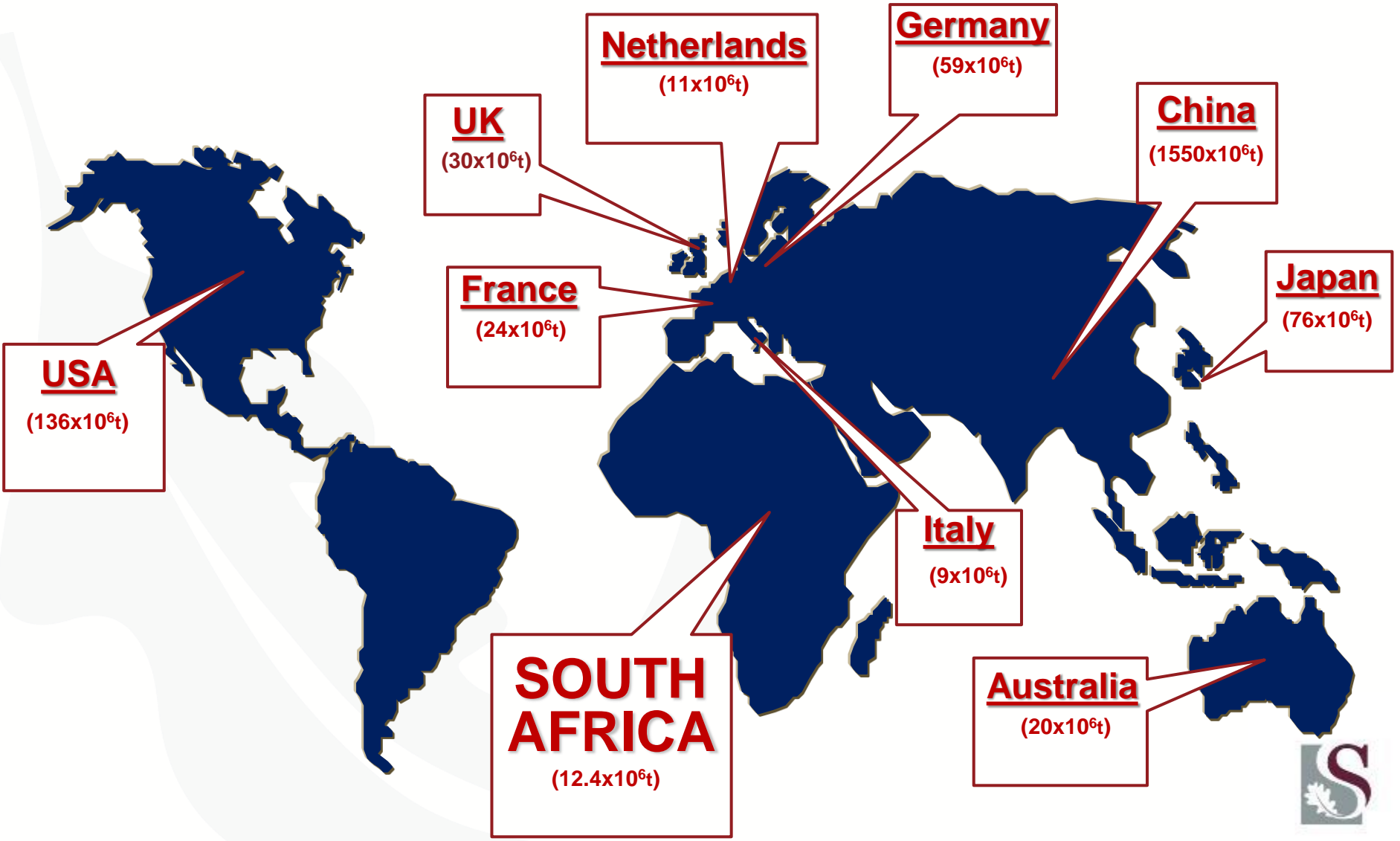




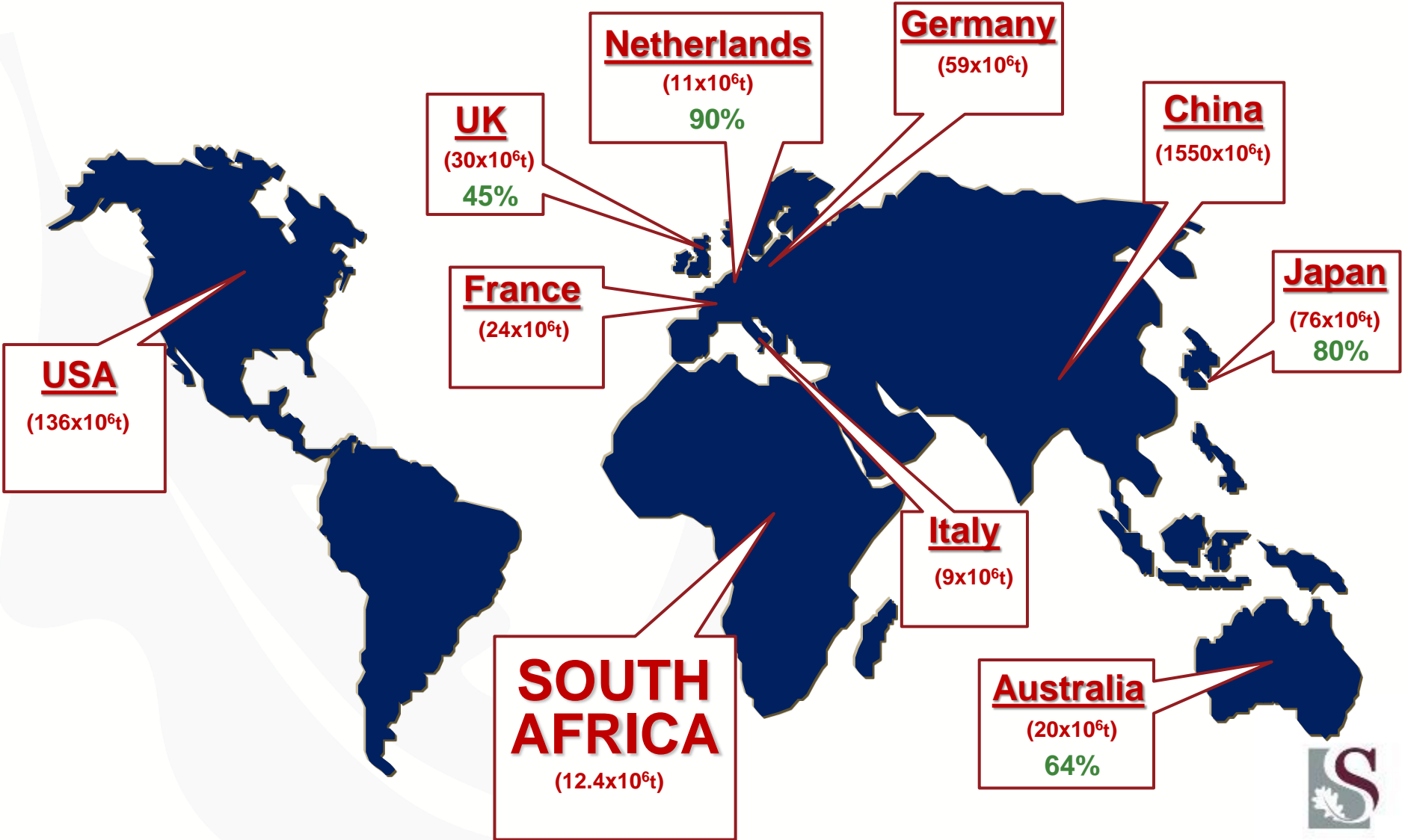




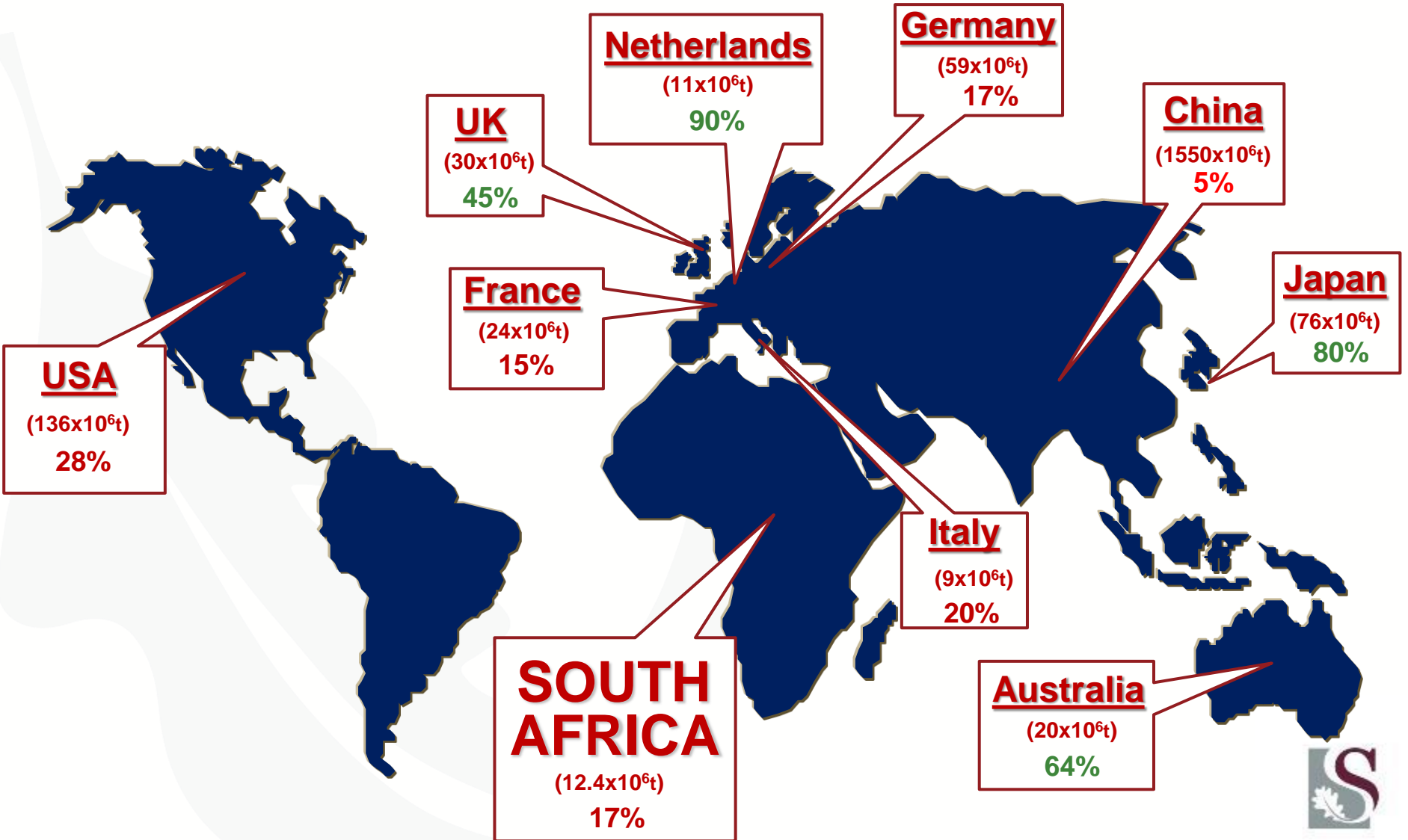
# Global statistics



# Global statistics



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# Global statistics

Nederlandse norm  
**NEN-EN 14227-2**  
 (en)

Hydraulisch gebonden mengsels - Specificatie  
 Deel 2: Met slak gebonden mengsels van korrelvormige materialen

Hydraulically bound mixtures - Specification  
 Part 2: Slag bound granular mixtures

Constituent		Main	Decor.	Finest
A	B			
Crushed aggregate	Crushed aggregate			
Other crushed aggregate	Other crushed aggregate			
Crushed aggregate with a part of other crushed aggregate	Crushed aggregate with a part of other crushed aggregate			
Other crushed aggregate	Other crushed aggregate			
Light weight aggregate	Light weight aggregate			
Crushed aggregate	Crushed aggregate			
Gypsum	Gypsum			
Plastics	Plastics			
Decomposed remains	Decomposed remains			

1: at A+B > 80% a granular material is classified as a mass

Nederlandse norm  
**NEN-EN 933-3**  
 (en)

Beproevingmethoden voor geometrische eigenschappen van toeslagmaterialen - Part 3: Bepaling van korrelvorm - Vlakheidsindex

Tests for geometrical properties of aggregates - Part 3: Determination of particle shape - Flakiness index

Nederlandse norm  
**NEN-EN 933-1**  
 (en)

Beproevingmethoden voor geometrische eigenschappen van toeslagmaterialen - Bepaling van de korrelgrootteverdeling - Zeefmethode

Tests for geometrical properties of aggregates - Part 1: Determination of particle size distribution - Sieving method

Nederlandse norm  
**NEN-EN 1097-2**  
 (en)

Beproevingmethoden voor de bepaling van mechanische en fysische eigenschappen van toeslagmaterialen - Deel 2: Methoden voor de bepaling van de weerstand tegen verbrijzeling

Tests for mechanical and physical properties of aggregates - Part 2: Methods for the determination of resistance to fragmentation

Versangt NEN-EN 14227-2  
 NEN-EN 14227-2:2011

ICS 01.040.93:91

Ver  
 ICS 01.040.93:91  
 januari 2011

Versangt NEN-EN 933-1  
 NEN-EN 933-1:1997/AC1  
 NEN-EN 933-1:1997/A  
 NEN-EN 933-1:1997/C  
 NEN-EN 933-1:2011

ICS 01.100  
 januari 2011

Versangt NEN-EN 1097-2:1998  
 NEN-EN 1097-2:1998/A1:2008  
 NEN-EN 1097-2:2009  
 Ontw.

ICS 01.100.15:93.080.20  
 april 2010



## Problem Statement

### Why does SA not divert to alternatives???

- Supply and quality

### Virgin materials is not always better

- Cape quarries clay content
- New borrowpits take longer than 9 months to get approval

### It has monetary value

- CoCT at cost of landfilling at **R400/t**, cost savings will be R224 million from diverting 60% of material from 2015 baseline data in 1 year..... In perspective Capex for CoCT 2016/17 = R237 million
- Cost savings could be **95%** of capex budget for 2016/17
- Illegal dumping – **R350** million per year





# Problem Statement



# Problem Statement



**Recycled concrete aggregate and masonry**

**=**

**RCA + RM = RCM**



# Comparing the South African situation with other countries



Surface

Base

Subbase

Subgrade

**Asphalt Layer**  
(20 - 50 mm)

**Unbound high quality crushed aggregate**  
(100 - 300mm)

**Cemented mixture**  
(100 - 300mm)

**Soil fill and unbound Mixture (Natural and selected)**

## South Africa



**Asphalt layer**

Subbase

Capping

Subgrade

**> 100 mm**  
**(asphaltic layer(s))**

**Unbound/hydraulically bound**

**Soil fill**

**Soil fill**

## Industrialised Countries



**Phase 1**

①



# Summary

	RCA-New	Unexposed	RCA-G1
Stress-strain form			
Ultimate strain decrease	0.0015 → 0.00095 $\epsilon_{f,1} \text{ 63\%} < \epsilon_{f,0}$	0.0025 → 0.00170 $\epsilon_{f,1} \text{ 68\%} < \epsilon_{f,0}$	0.0025 → 0.0022 $\epsilon_{f,1} \text{ 88\%} < \epsilon_{f,0}$
Monotonic			
pH/	13.1	11.9	10.9
Phenolphthalein/		-	
Intensity	28000	-	0



Layout >> Phase 2

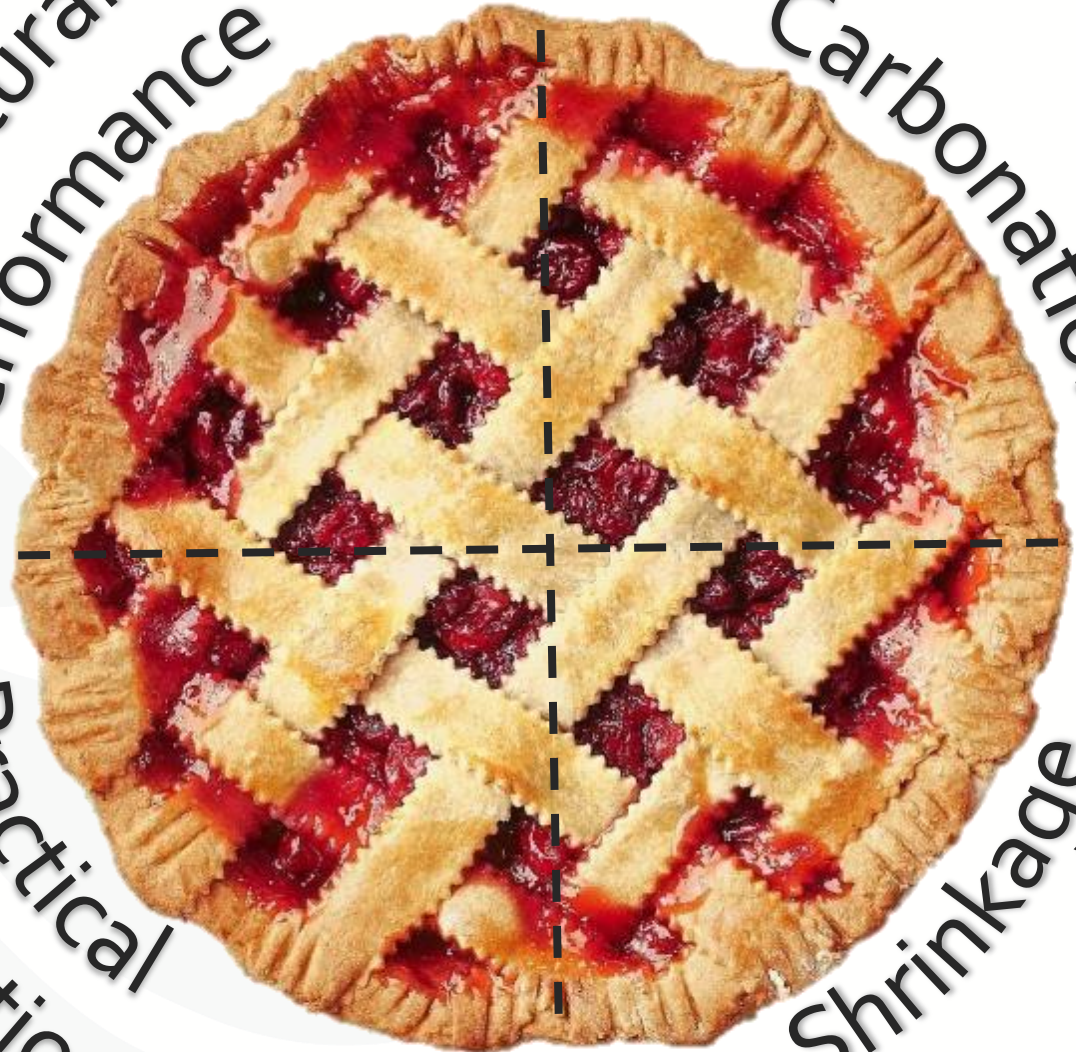
②

Structural Performance

Carbonation

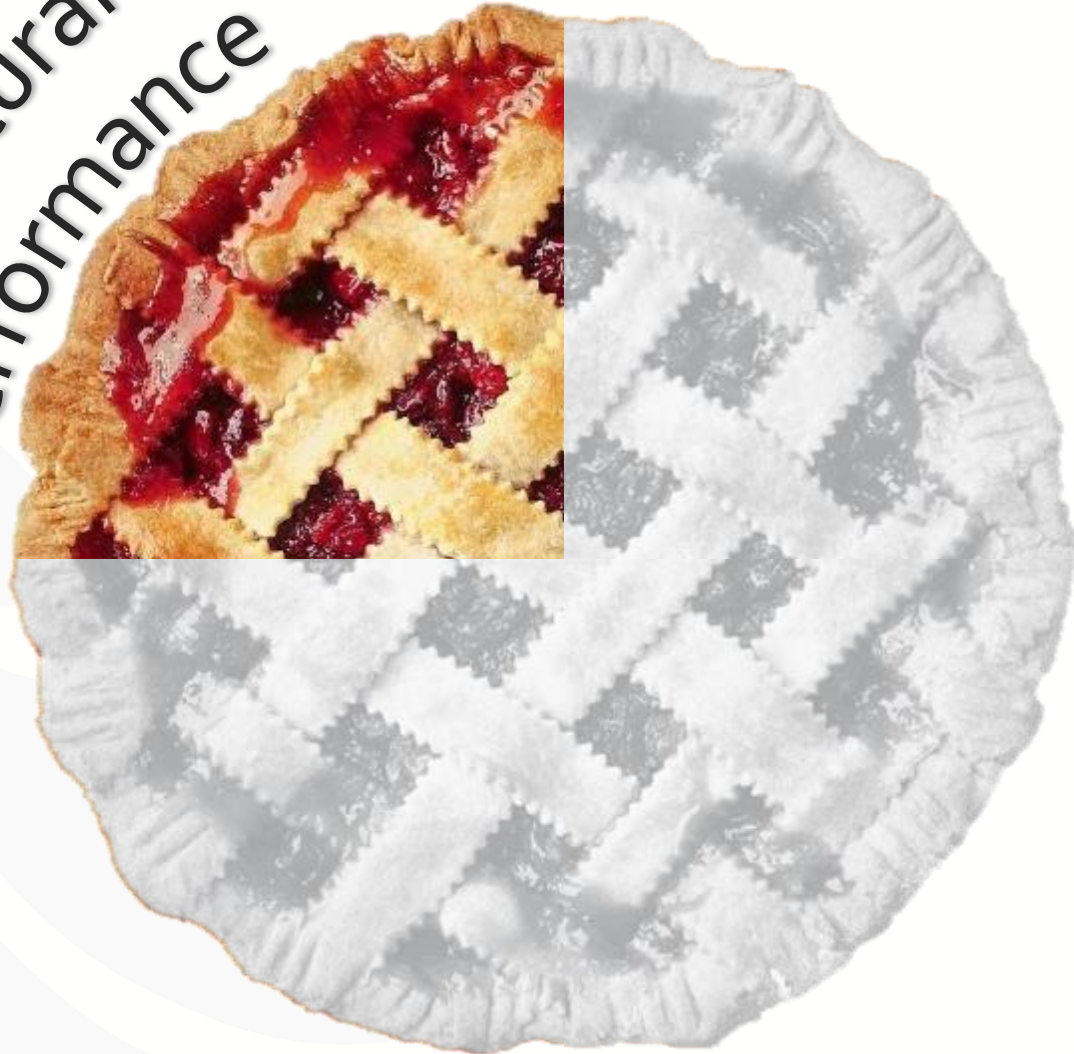
Practical Application

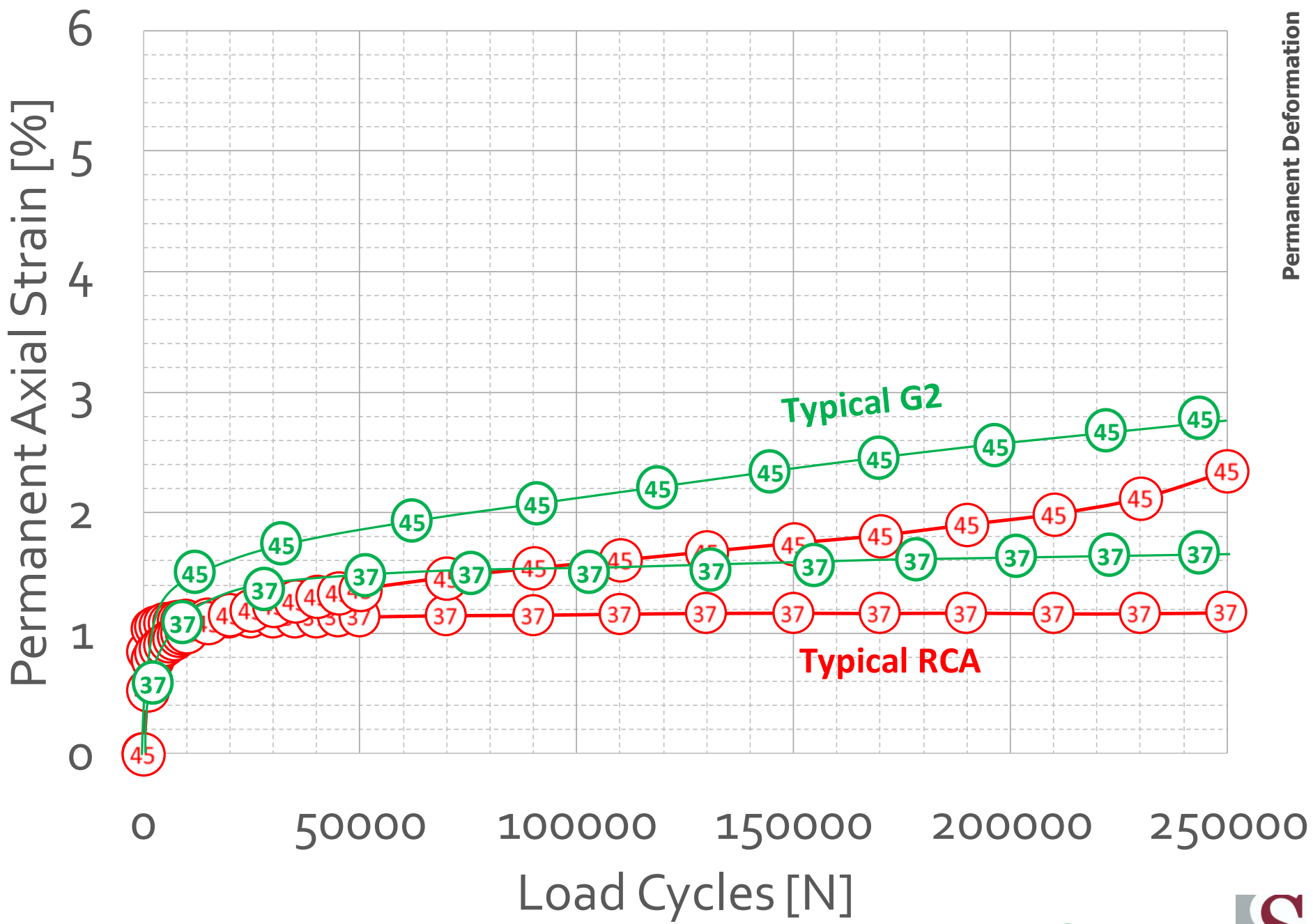
Shrinkage



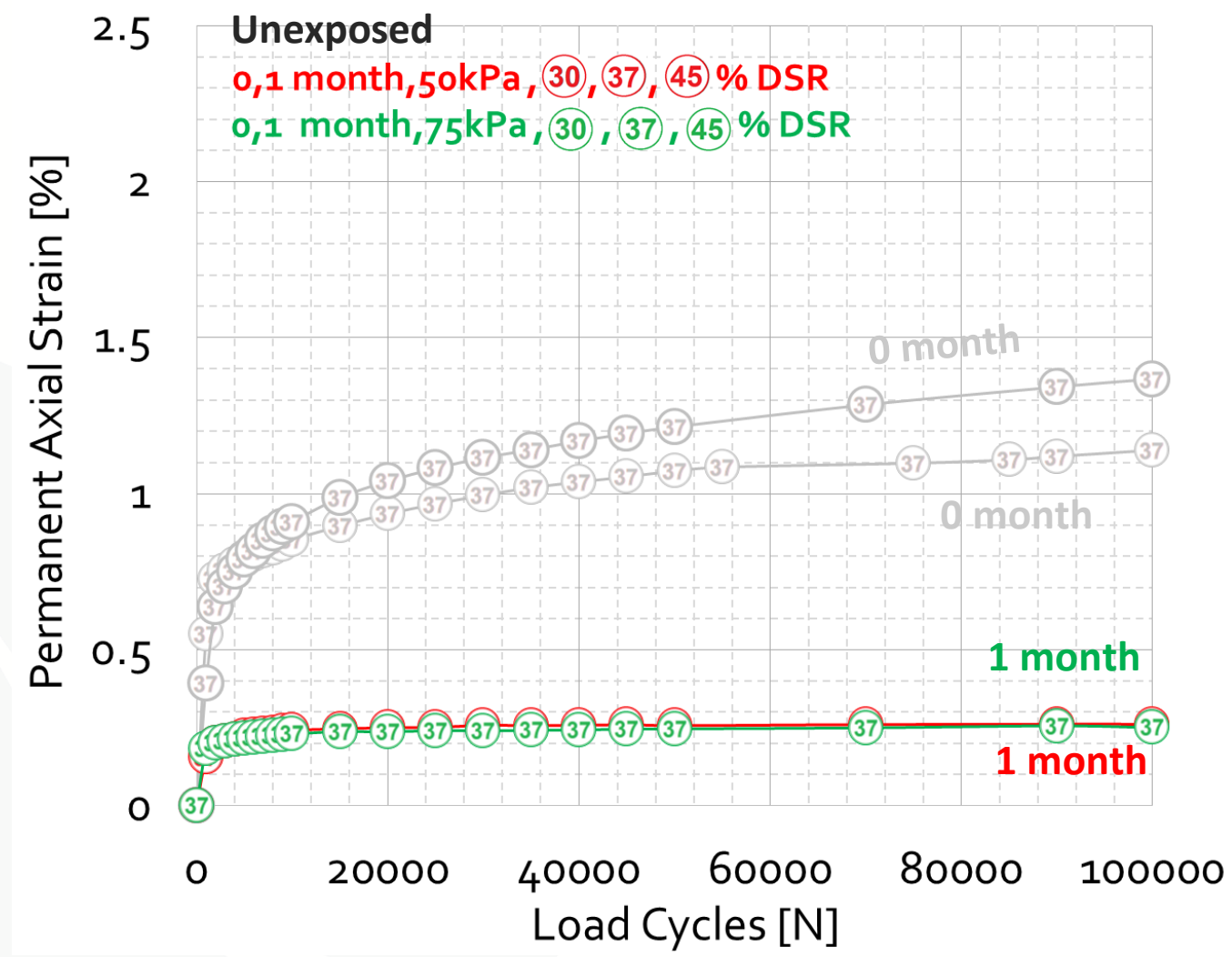
# Structural behaviour

Structural Performance

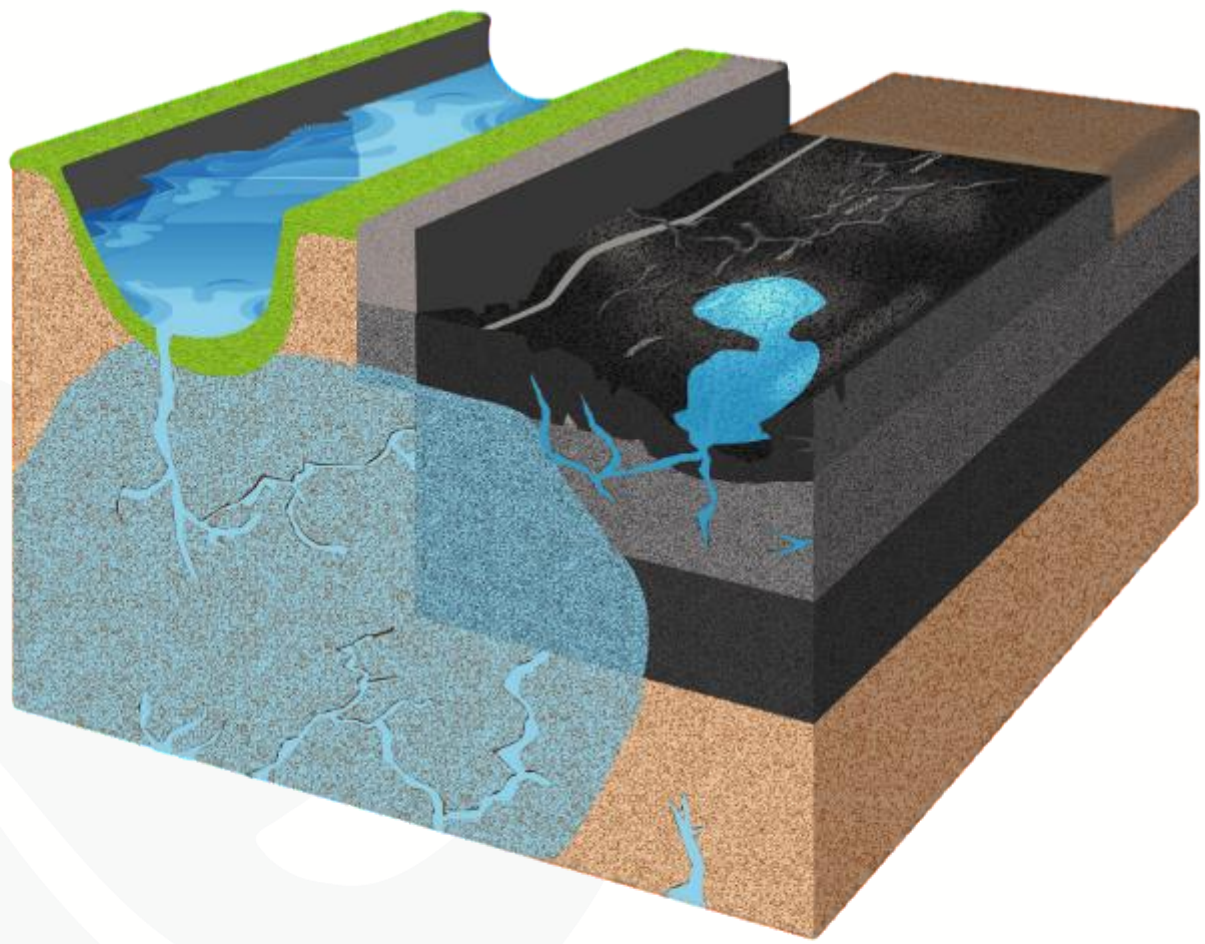




**Permanent Deformation >> Unexposed >> 0 month vs 1 month**

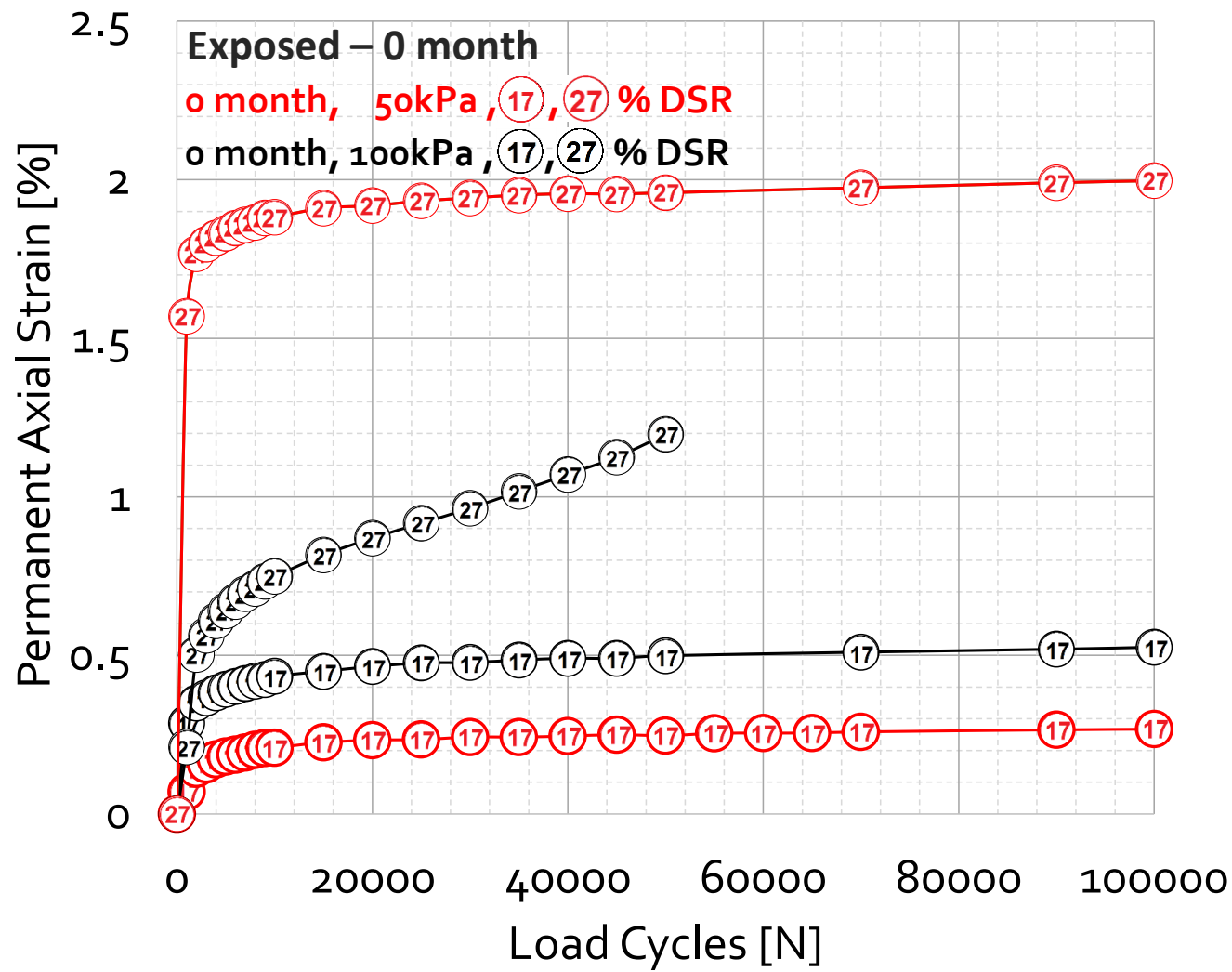


**Permanent Deformation >> Durability is an issue**

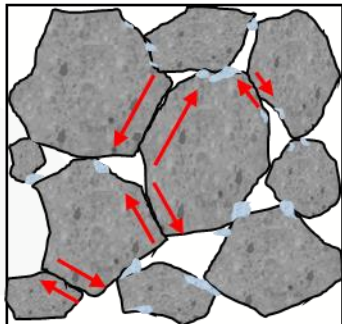
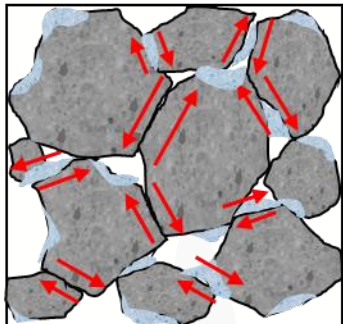
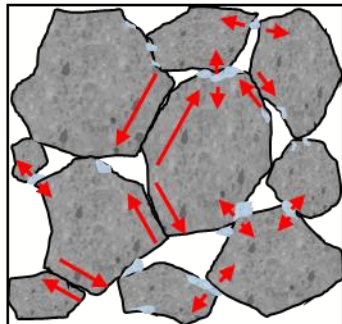
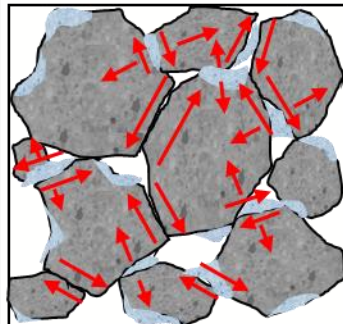




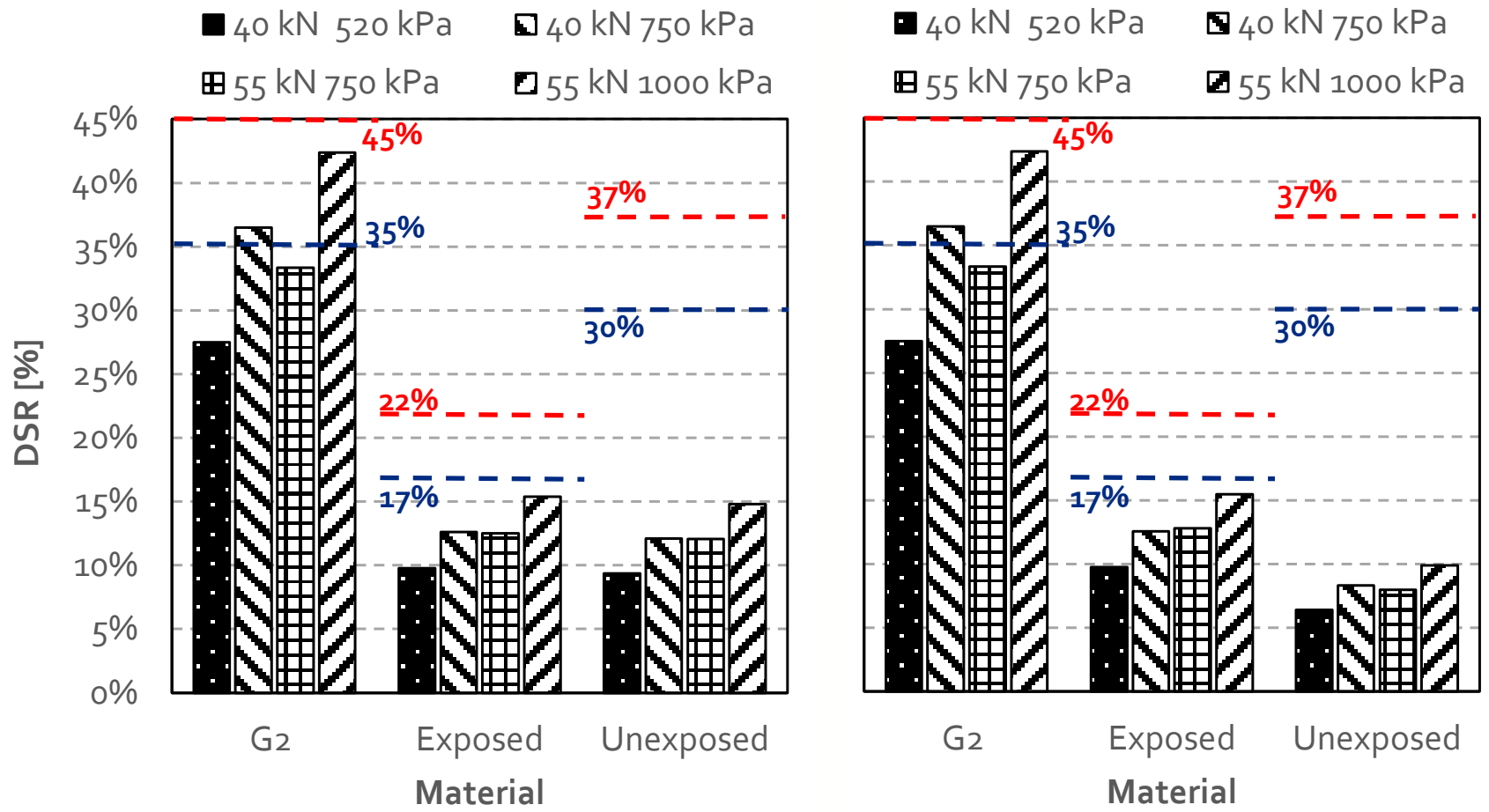
**Permanent Deformation >> Exposed >> 0 month**



**Defining Boundaries >> Summary**

	Exposed 0 month	Unexposed 0 month	Exposed 1 month	Unexposed 1 month
Processing + self-cementation				

**Pavement Analysis >> Pavement 2 >> DSR comparison**



DSR= Deviator stress ratio

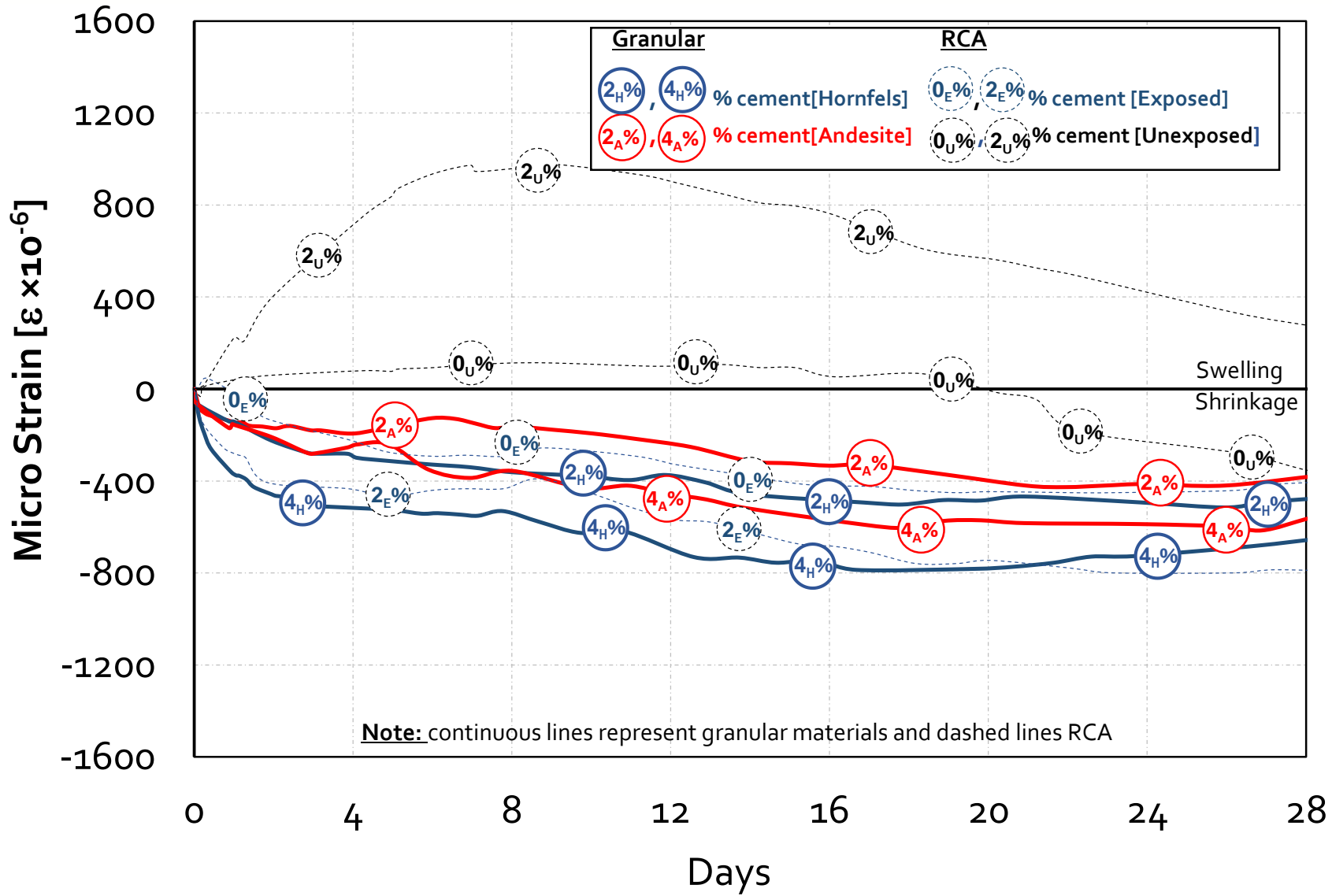


# Shrinkage

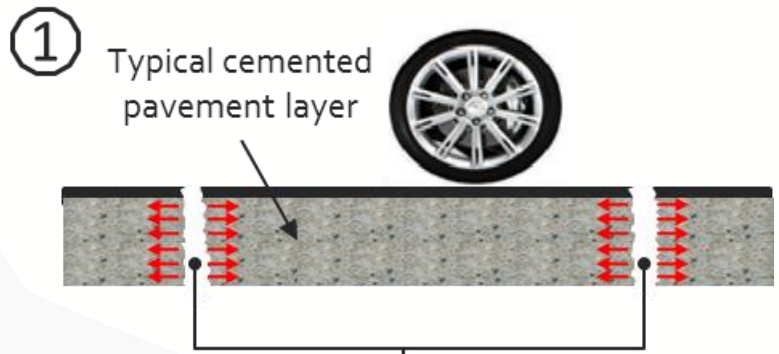


Shrinkage

# Shrinkage >> Experimental Data

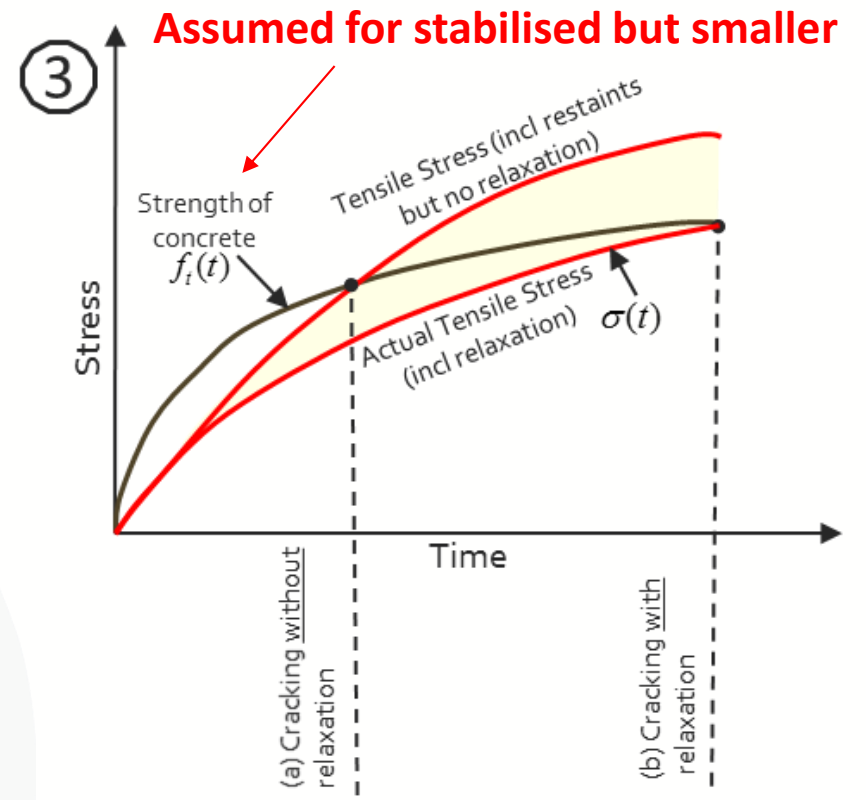


# Shrinkage >> Theory

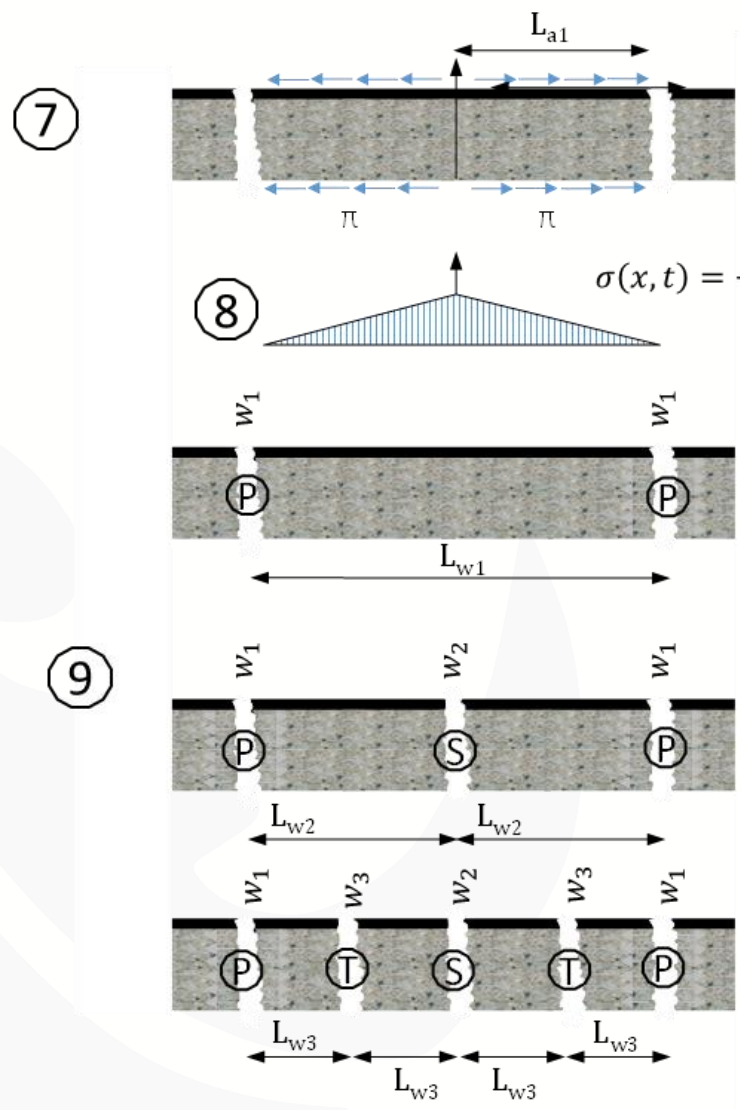


②  $\sigma(t) > f_t(t)$

④  $\sigma(t) = \varepsilon(t) \cdot R(t) \cdot E(t)$



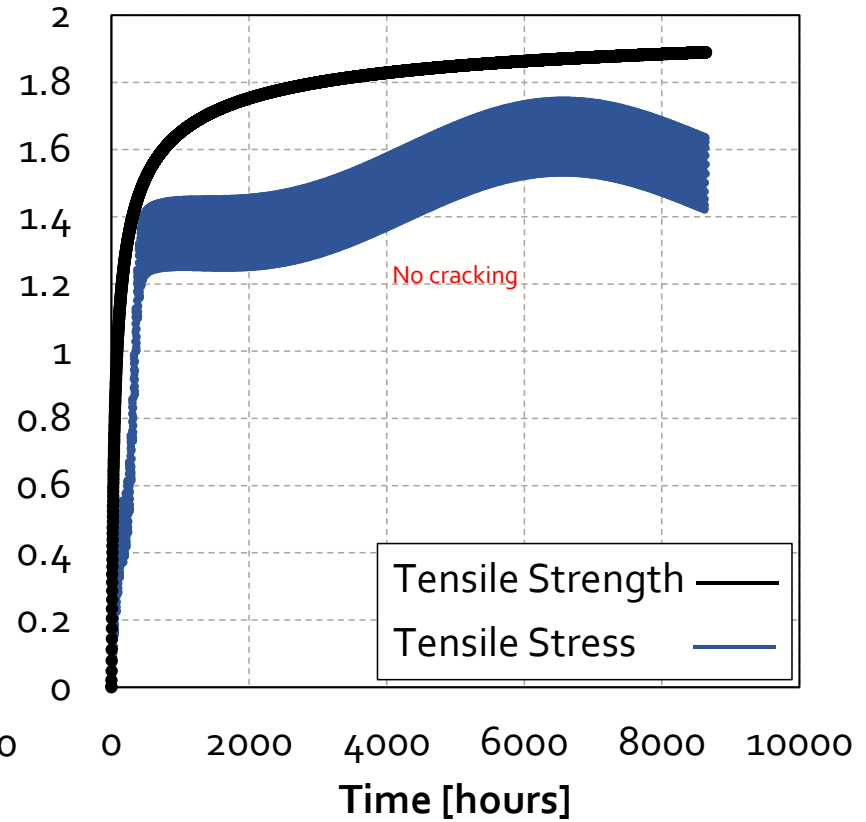
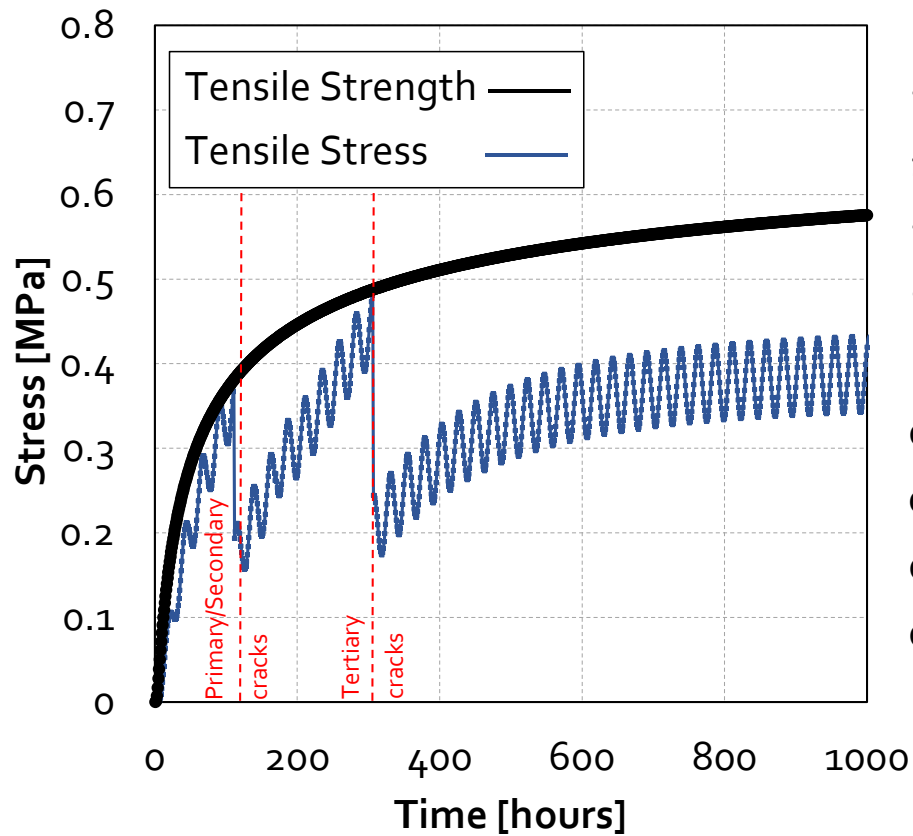
# Shrinkage >> Houben Model



- (P) = Primary cracks
- (S) = Secondary cracks
- (T) = Tertiary cracks

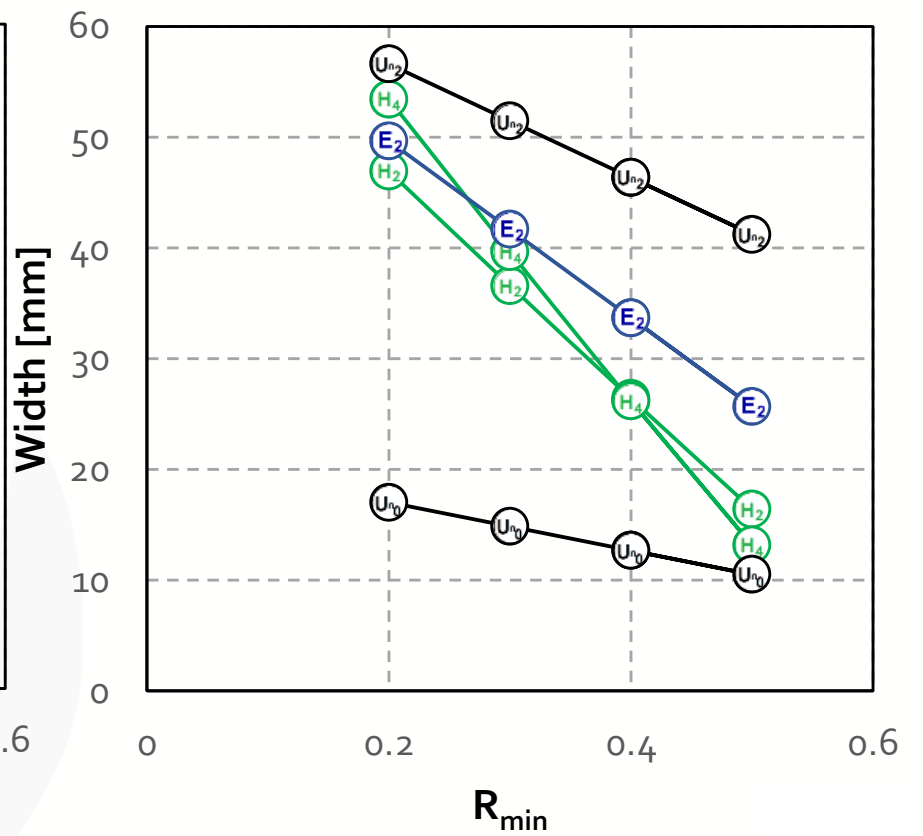
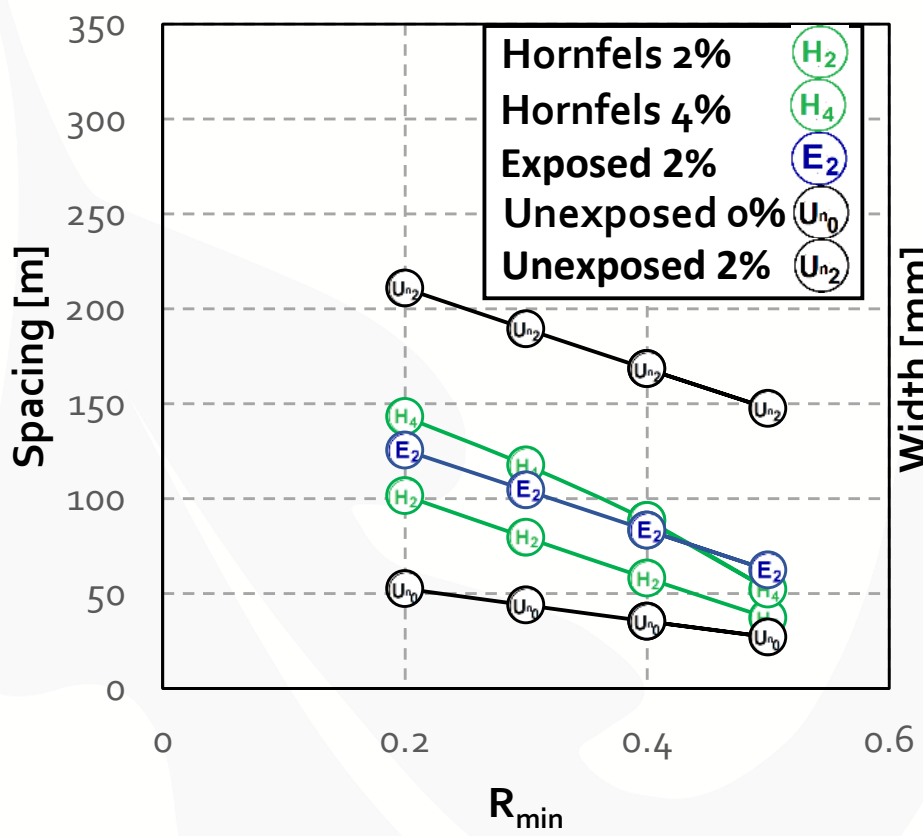


Shrinkage >> Houben Model >> Typical Output

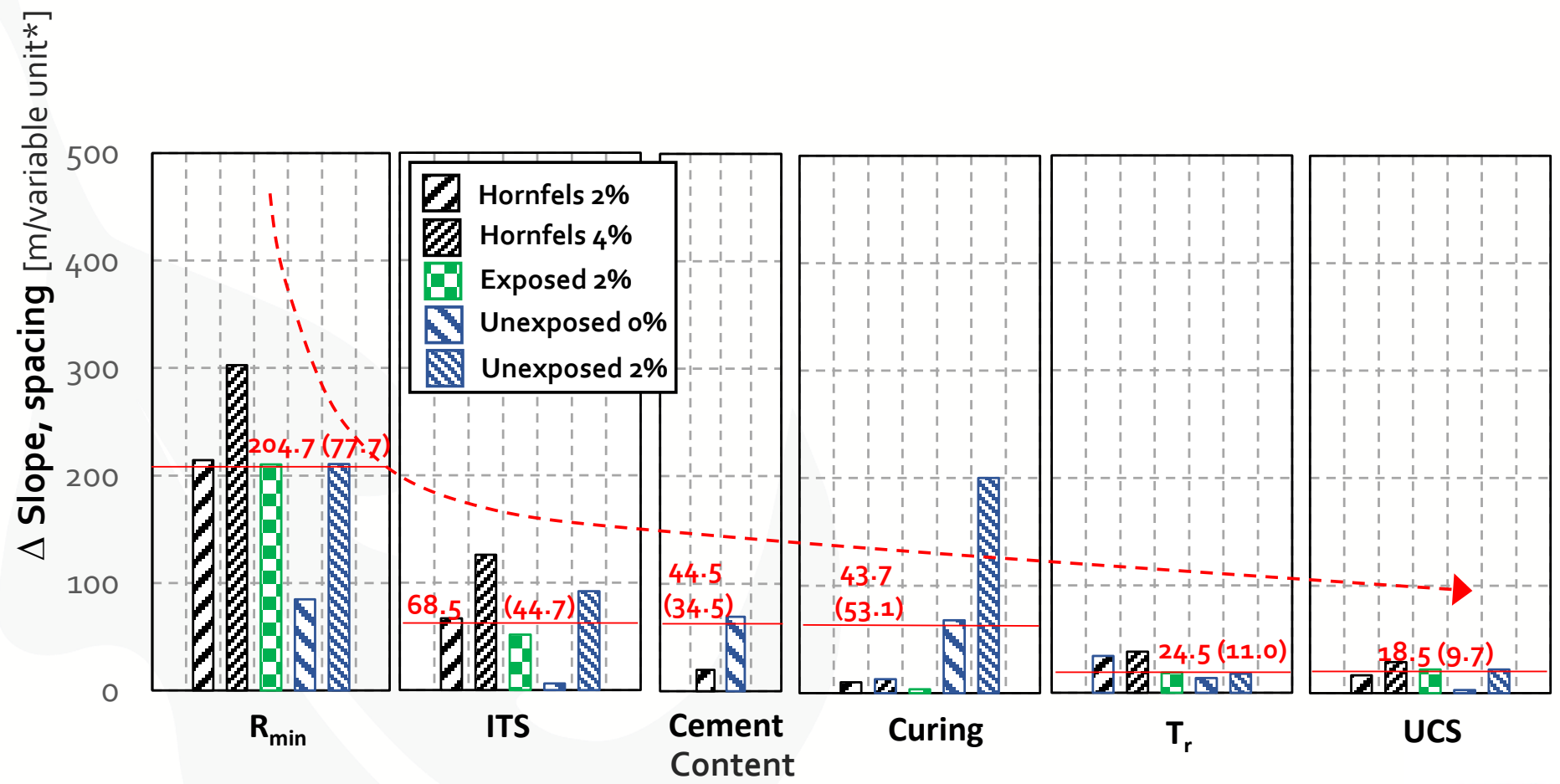




**Shrinkage >> Sensitivity analysis >> Empirical Models >>  $R_{min}$**



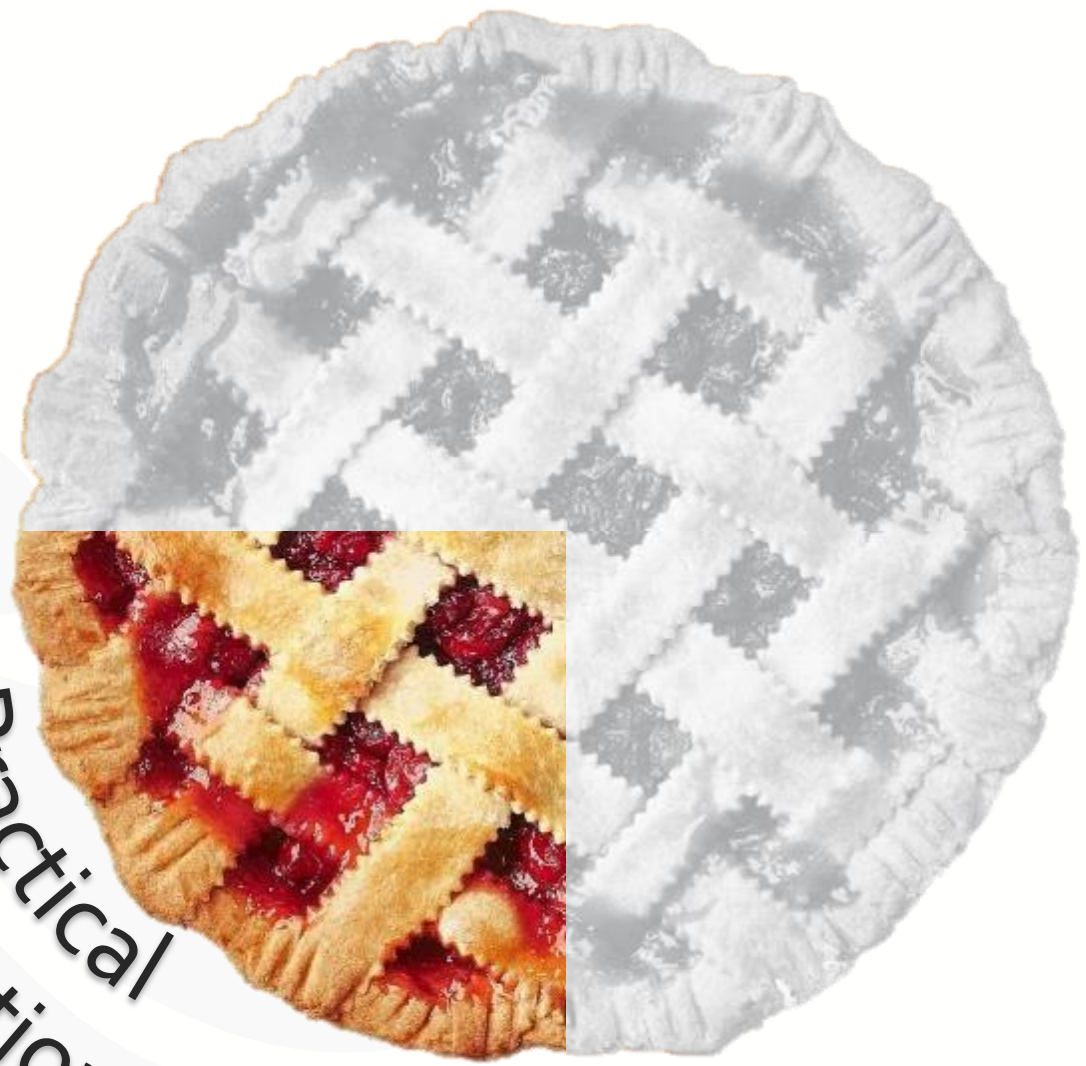
**Shrinkage >> Sensitivity analysis >> Ranking Variables**



\* measured against unit of x axis







# Practical Considerations



Practical Application

# Proposed guidelines

	In-situ/ immediate construction [Unexposed]	Stockpile [Exposed + Unexposed]	Stockpile [Exposed]
Processing sampling	✓		✓
	✓		✓
	✗		[✓]
Turning and wetting of stockpiles preferred			
Sampling	✗		[✓]
Testing	Immediately	Mix design to be rechecked before construction	No significant material response change
Testing frequency to be developed			



# Conclusions



- Response of material changes
- Origin of self-cementation varies



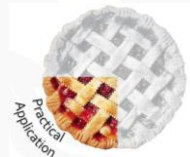
- Bound and unbound response
- Limits on stress ratio for Unexposed



- RCA susceptible to carbonation
- Moisture addition important



- RCA susceptible to shrinkage
- Cement must be added to mitigate shrinkage
- Less cement needed



- Unbound form, performs superior to conventional materials

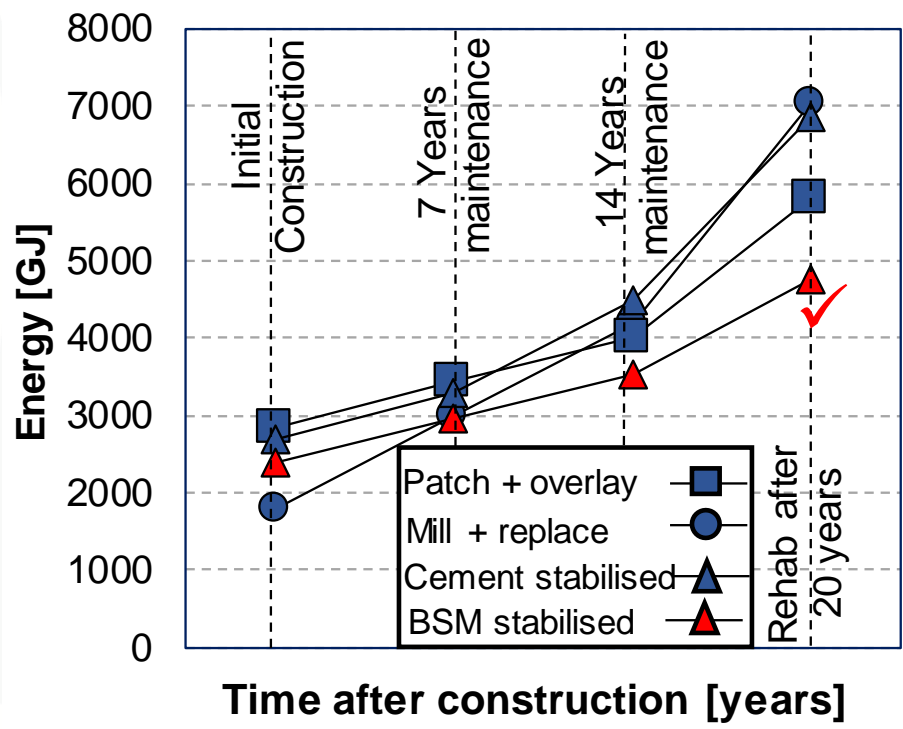


## The way forward

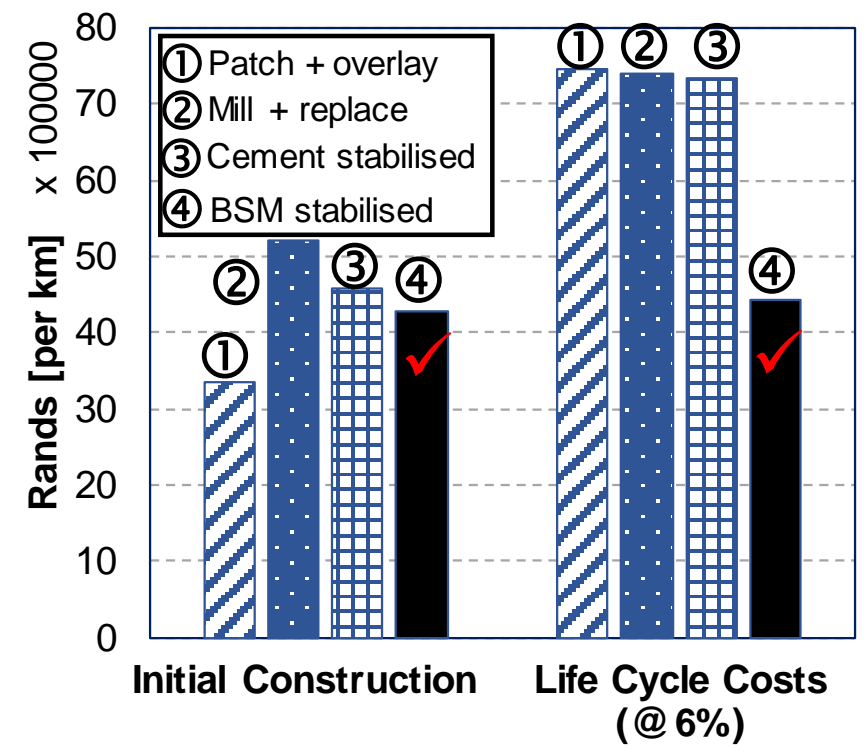
- **Uptake of RCA and RCM in the next five years will be significant**
- **Trial sections are being built in the next few months.**



# The way forward



Collings and Jenkins (2015)





## The way forward

- Uptake of RCA and RCM in the next five years will be significant

**Watch this space**

Flexibility of using material in other applications





Introduction

Origins self-  
cementation

Structural  
behaviour

**Durability**

Practical  
considerations

Conclusions

**THANK YOU**

