

# CLOSING THE LOOP OF COLD RECYCLING



forward together  
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saam vorentoe



1st International Workshop on  
Asphalt Recycling Technologies

9th and 10th September 2024  
RWTH Aachen | Germany



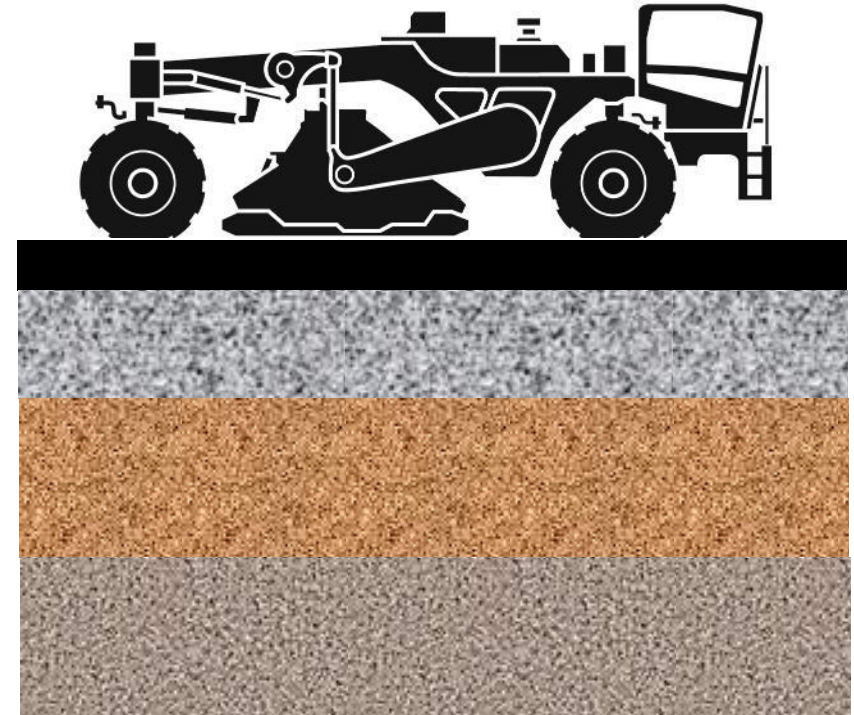
ART 2024

FROM RESEARCH TO APPLICATION,  
CREATING PERPETUAL CYCLES

# WHAT ARE THE GAME CHANGES? HOW TO IMPLEMENT?

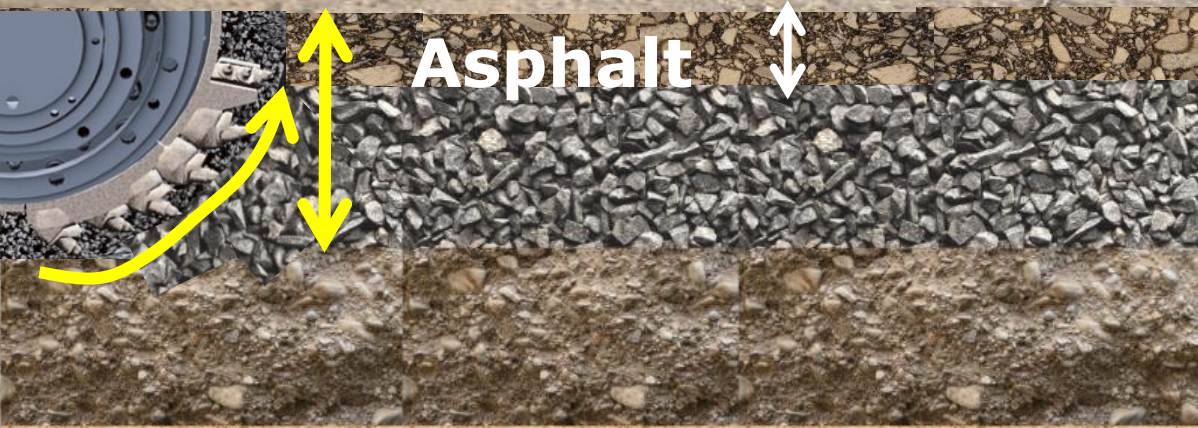


- ▶ Game Changes in **Recycling** (spectrum from cold to hot)
- ▶ Evolution of **Materials** (RC, RAP)
- ▶ Mix **Design** to Structural Design
- ▶ Improving **Test Methods**
- ▶ **Outcomes**



# TRACTION FOR COLD RECYCLING

**In situ Recycling  
< 50% RAP**



**In Situ Recycling 1990 onwards**

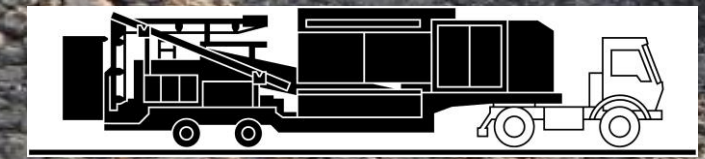
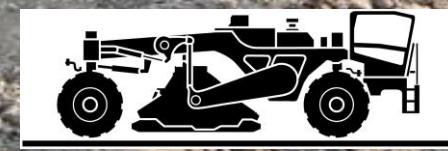
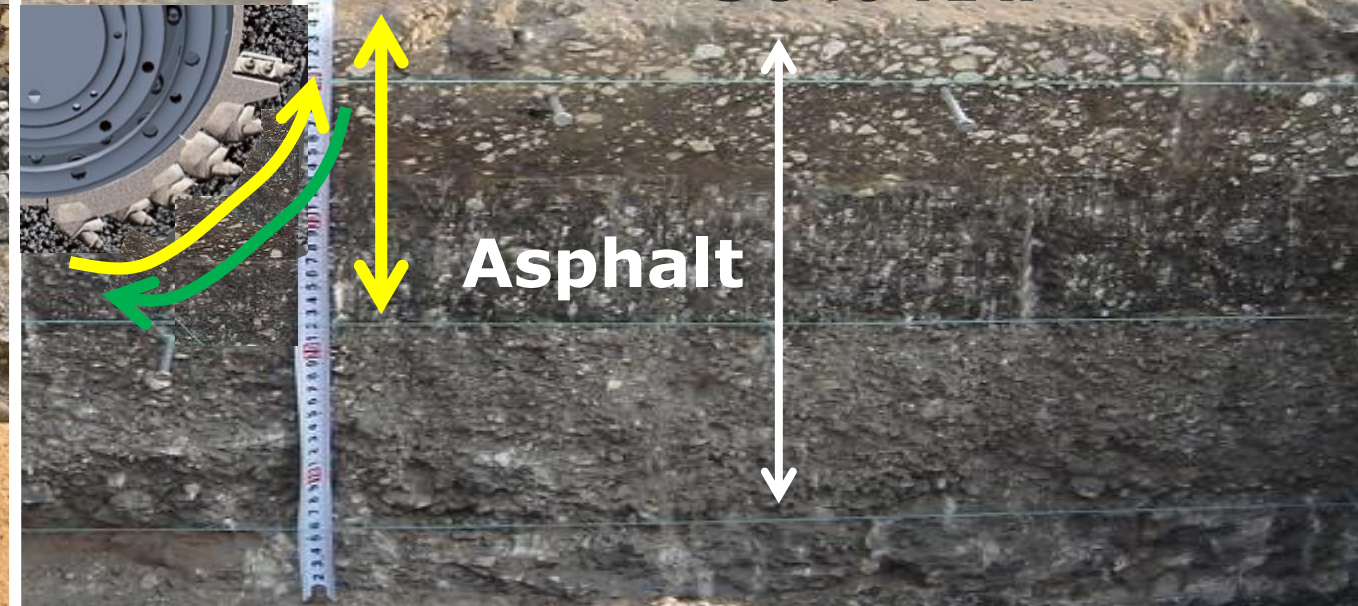


# AGGREGATES FOR COLD RECYCLING



**In situ Recycling  
< 50% RAP**

**In situ Recycling  
> 50% RAP**



**In Situ Recycling 1990 onwards**

**In Situ + In Plant Recycling 2000+**

# TECHNOLOGY OPTIONS



Emissions (%)

40-50

60-70

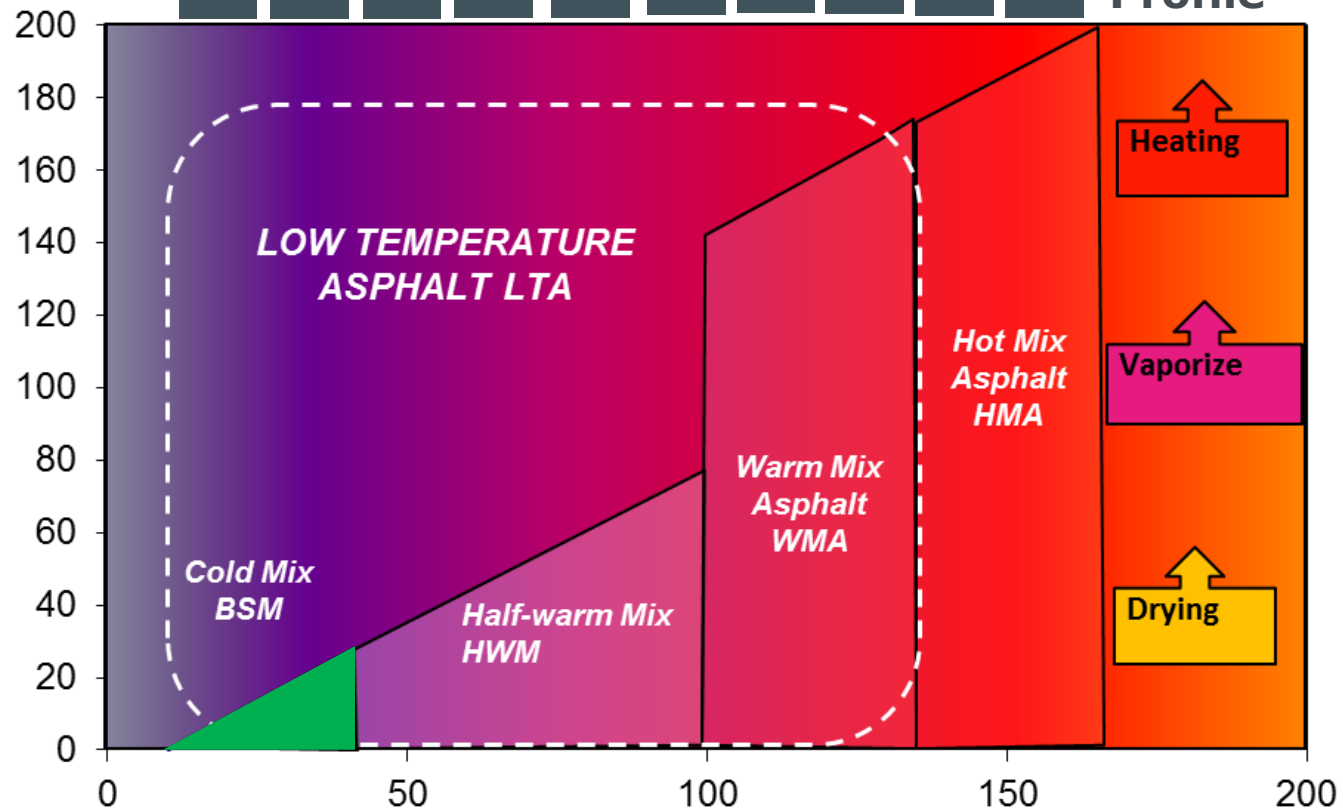
80-90

100

CO<sub>x</sub> NO<sub>x</sub> SO<sub>x</sub>

Implementation Profile

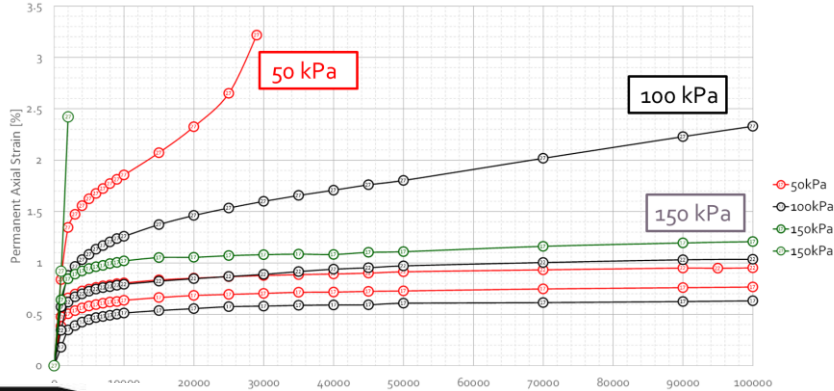
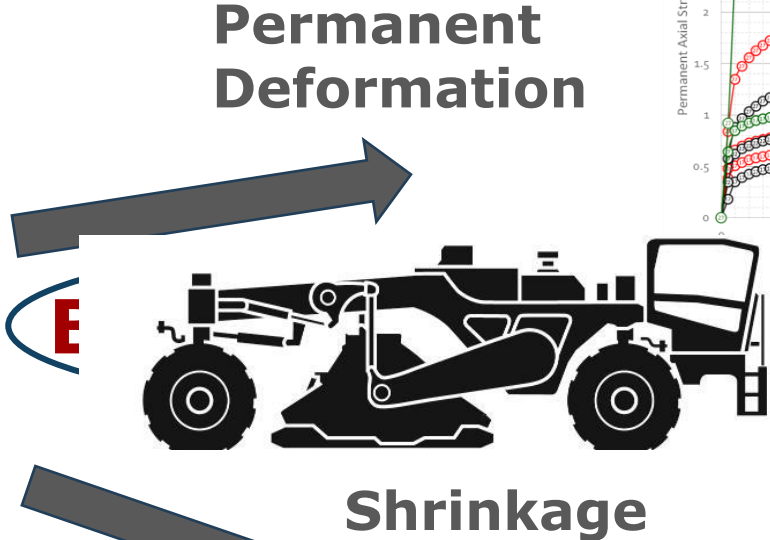
Energy consumption (MJ/ton)



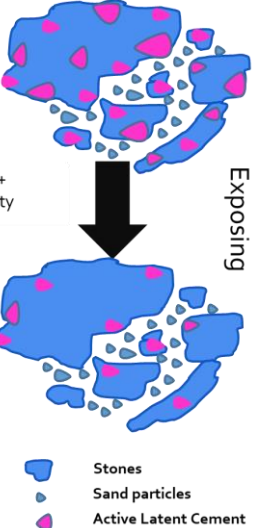
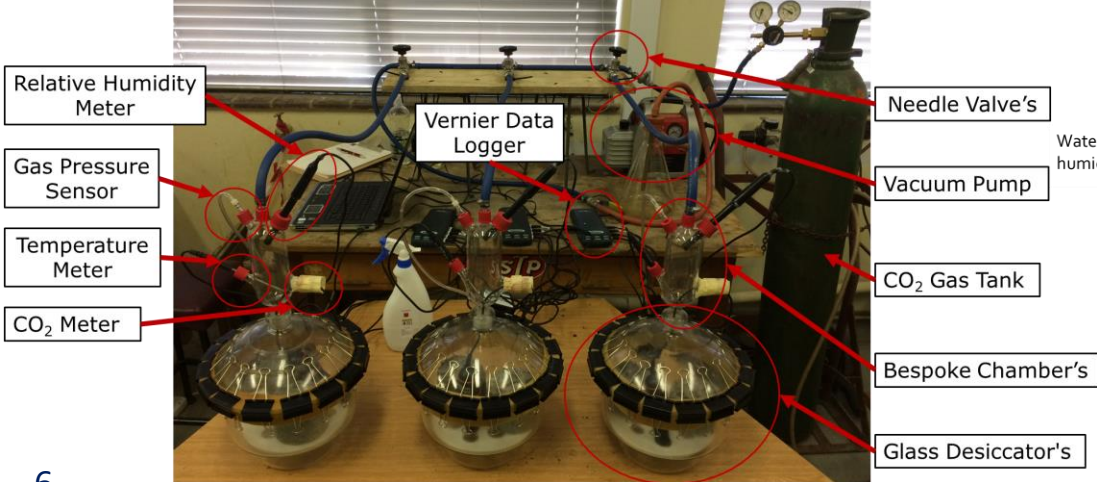
Aggregate Temperature (°C)

after (Jenkins, AAPT, 2001)

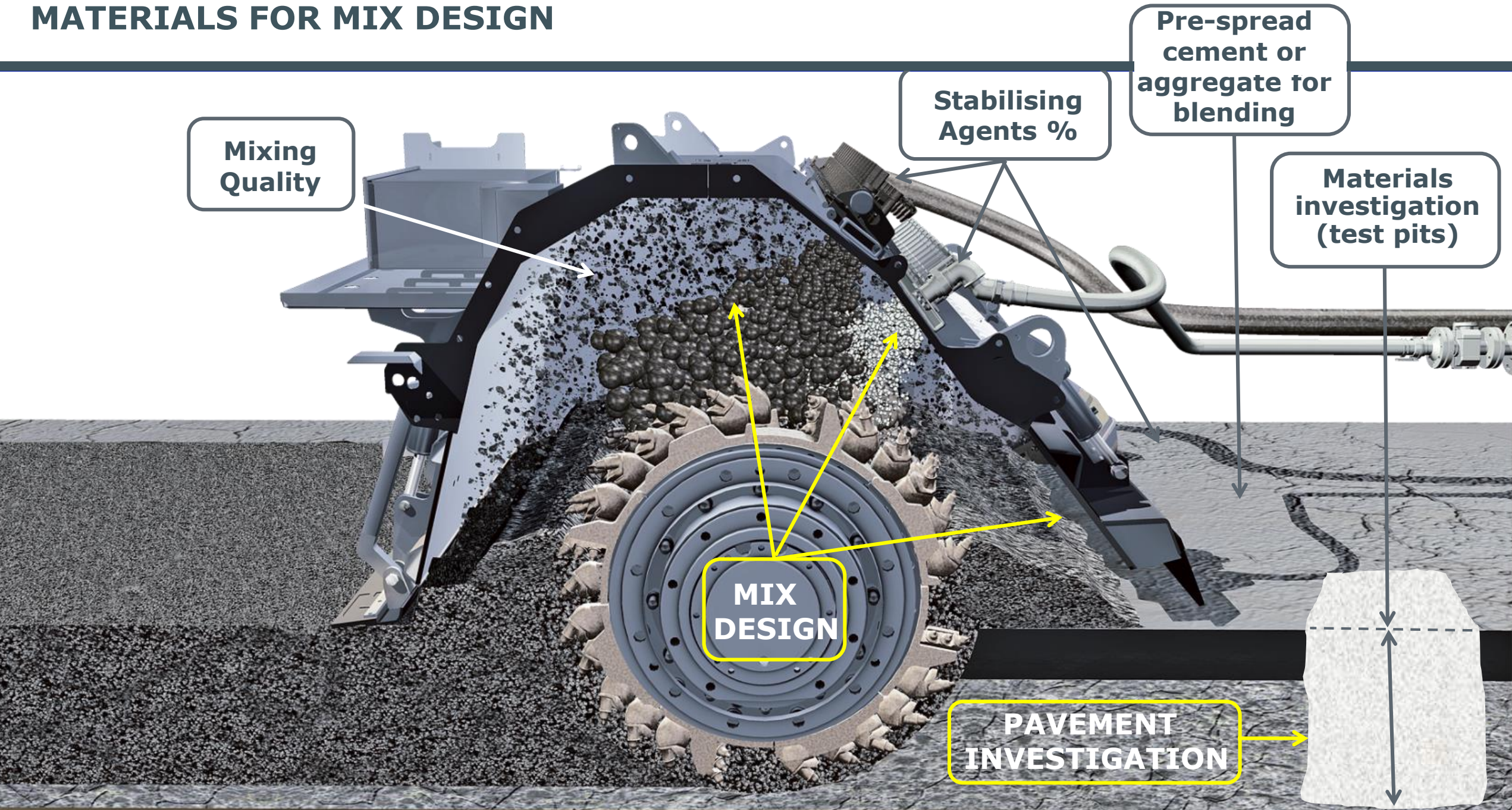
# Recyclable and Secondary Materials



Carbonation



# MATERIALS FOR MIX DESIGN



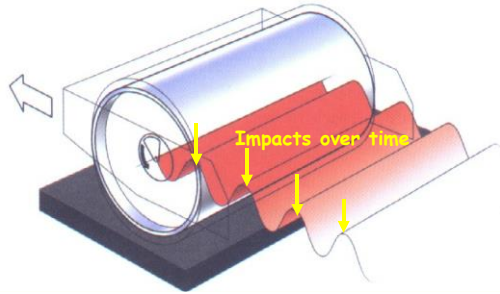
# MIX DESIGN: COLD RECYCLING IMPROVEMENTS



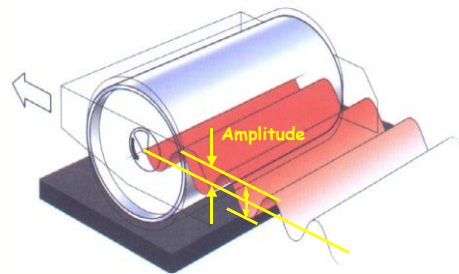
## Padfoot Dynamic Roller

## Drop Weight Hammer

Frequency - vpm (hz)



Amplitude - mm

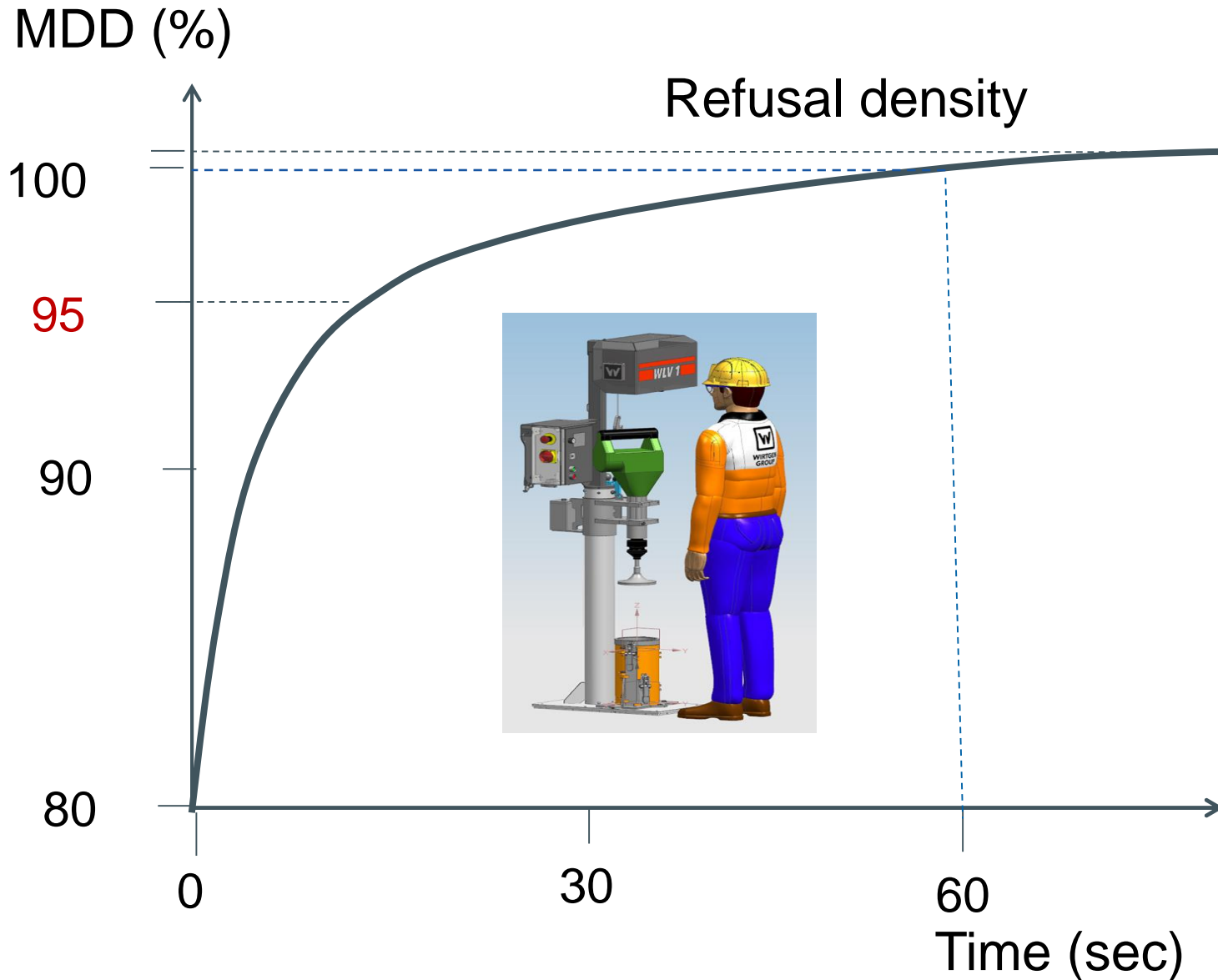


	Field (Vibro)
Frequency (Hz)	50 – 65
Amplitude (mm)	0.4 – 1

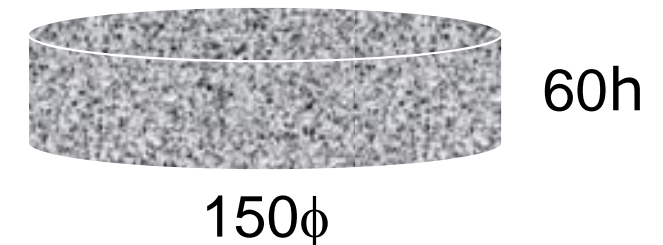
Lab (Mod.Proc)
1
457.2

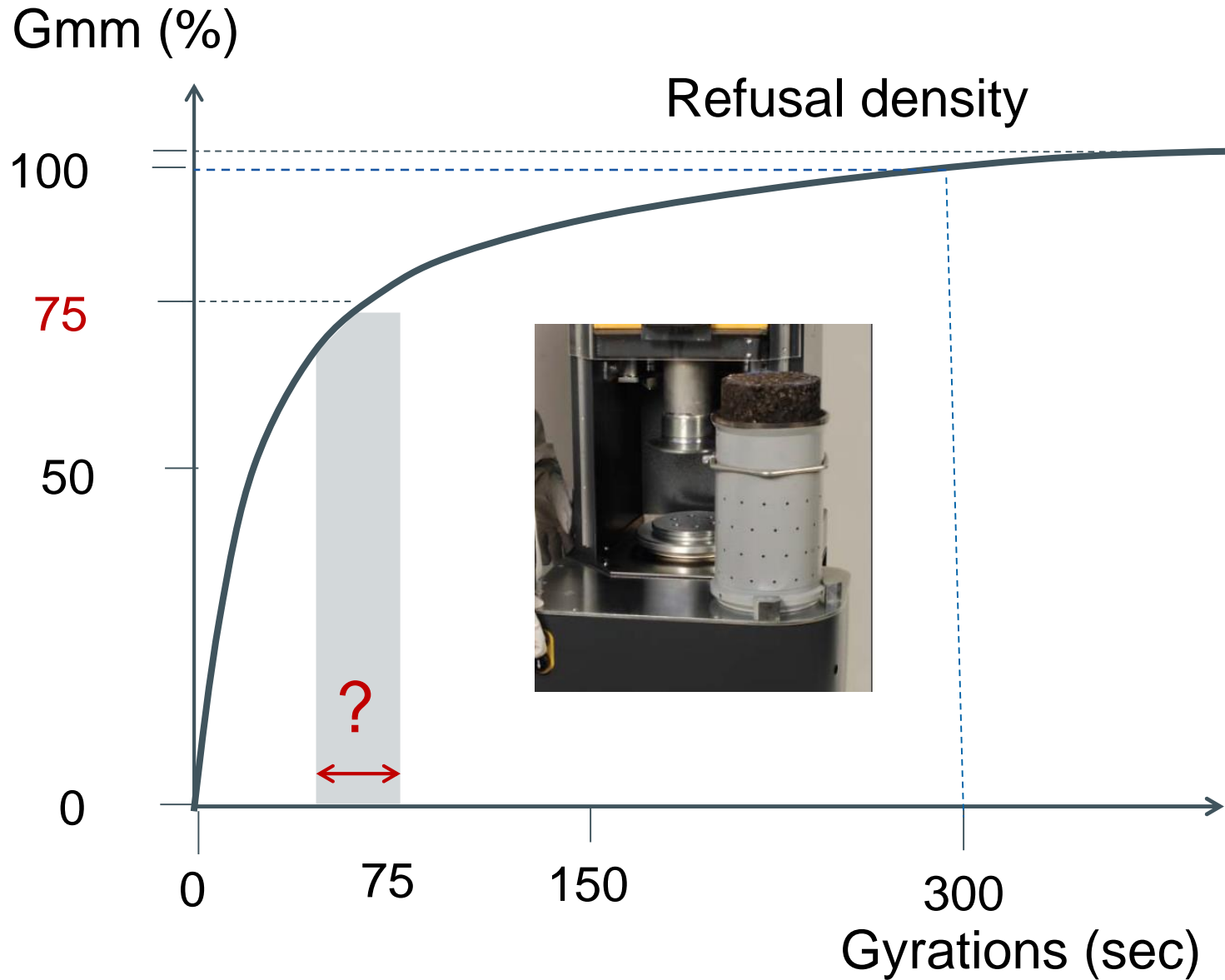


# ALTERNATE VIBRATORY COMPACTION (EU)

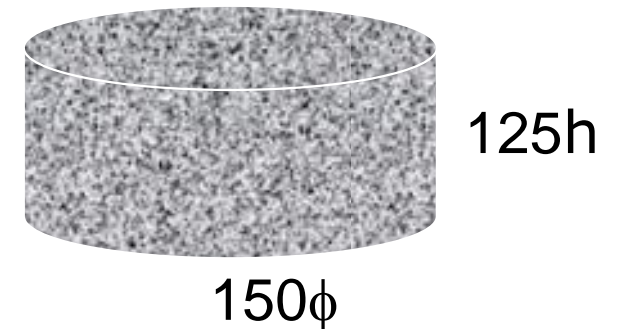


- **100% RA processed with impact crusher**
- **Mix Design**
  - 0.8 to 1% cement
  - 2 to 2.2% foamed bit
- **Lab specimen for ITS is 150 mm  $\phi$  x 60 mm h (& 95mm)**
- **Compaction: 100% MDD achieved with vib-hammer for 60 secs x 2 sub-layers**
- **Target for field compaction is 95% of MDD**





- **100% RA processed with impact crusher**
- **Mix Design**
  - 1% cement
  - 2 to 2.2% foamed bit
- **Lab specimen for ITS is 150 mm  $\phi$  x 125 mm h**
- **Gyratory Compaction: Range of # Gyration = Field Comp?**
- **Guidelines for Moisture Impact**



# ADVANCED MIX DESIGN – TRIAXIAL TEST



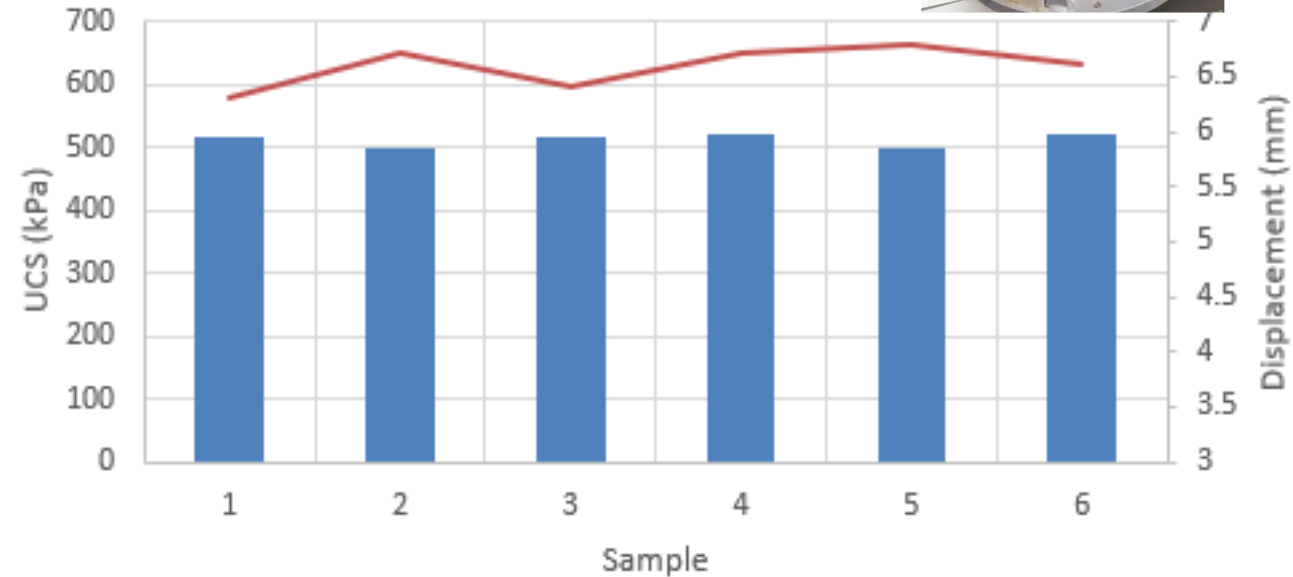
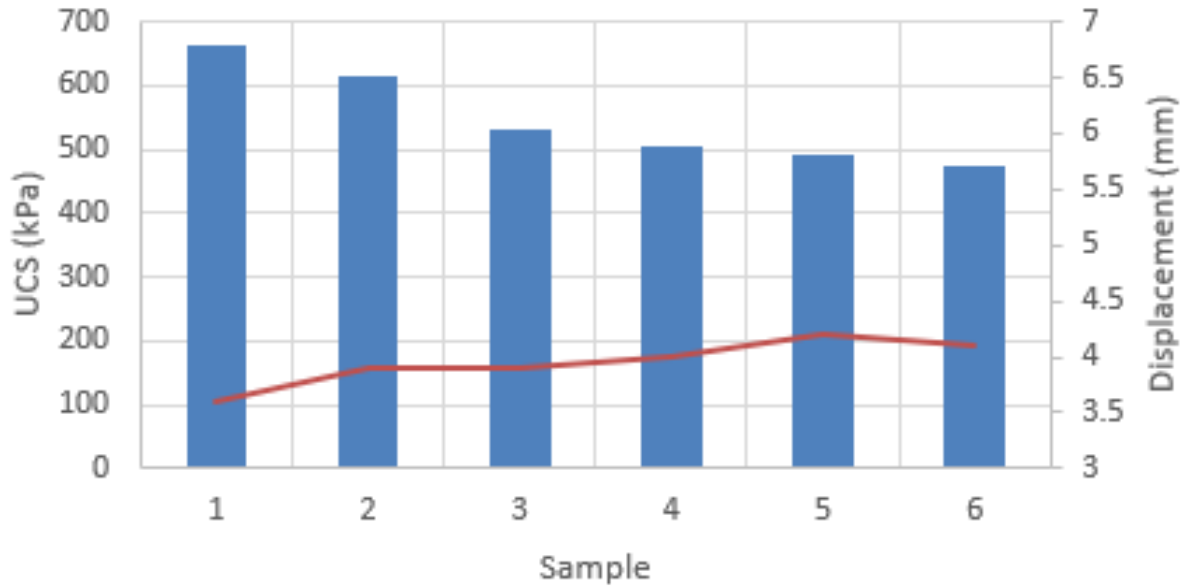
**Test at 25°C**

**Confining Pressure**  
0 kPa 50 kPa  
100 kPa 200kPa

# STACKING TRIAXIALS = QUALITY CONTROL

Specimens: 100% RA

Principle of Stacking: simple equipment  
(Compaction height < 150mm)



Standard Specimen

(Govender, 2023)

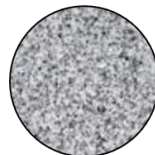
■ UCS — Displacement

300mm



Front View

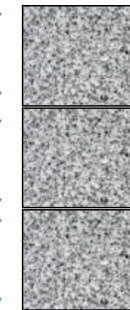
150mm



Top View

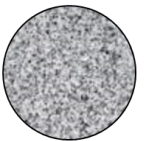
Stacked Specimen

100mm  
100mm  
100mm



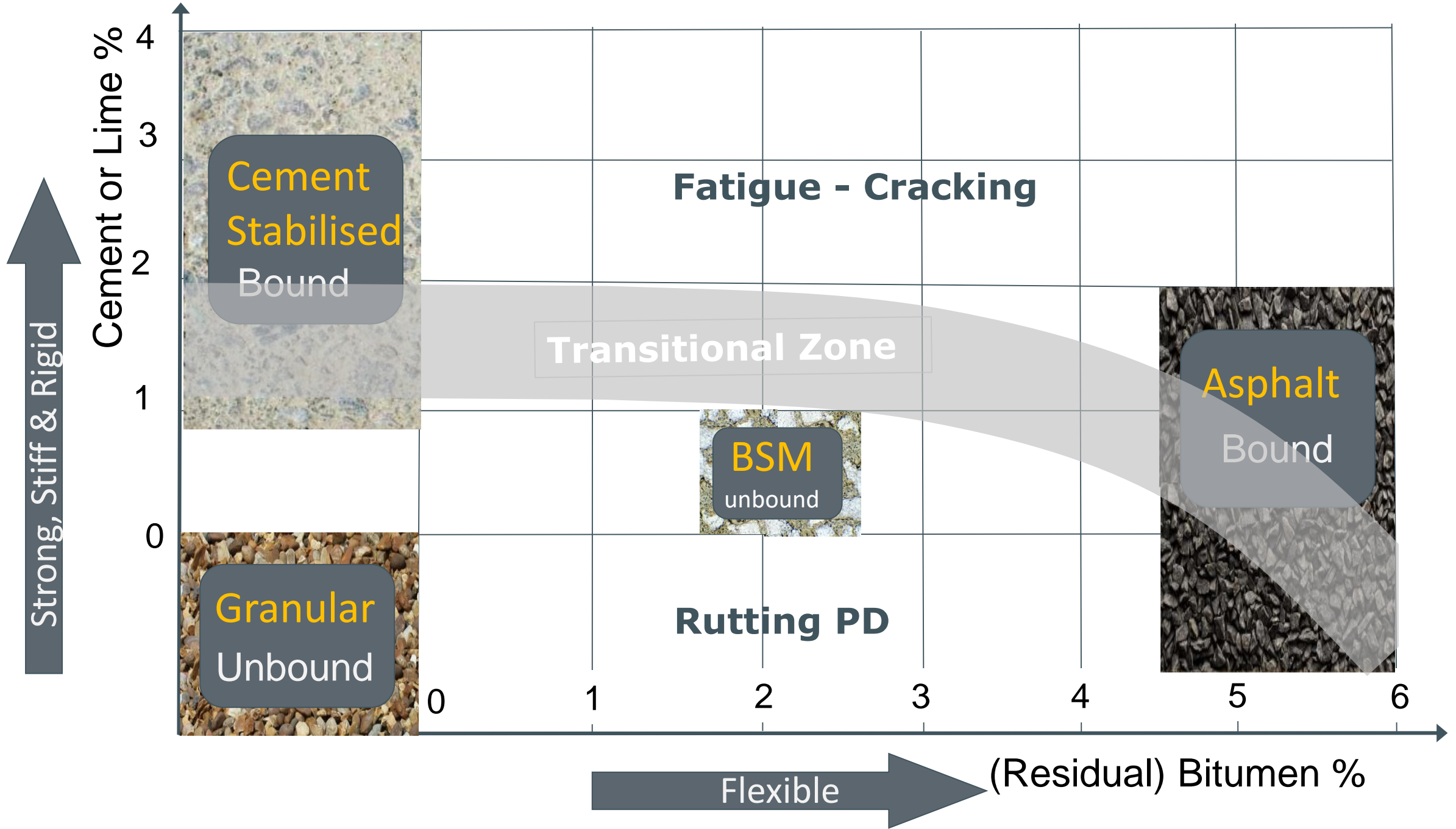
Front View

150mm

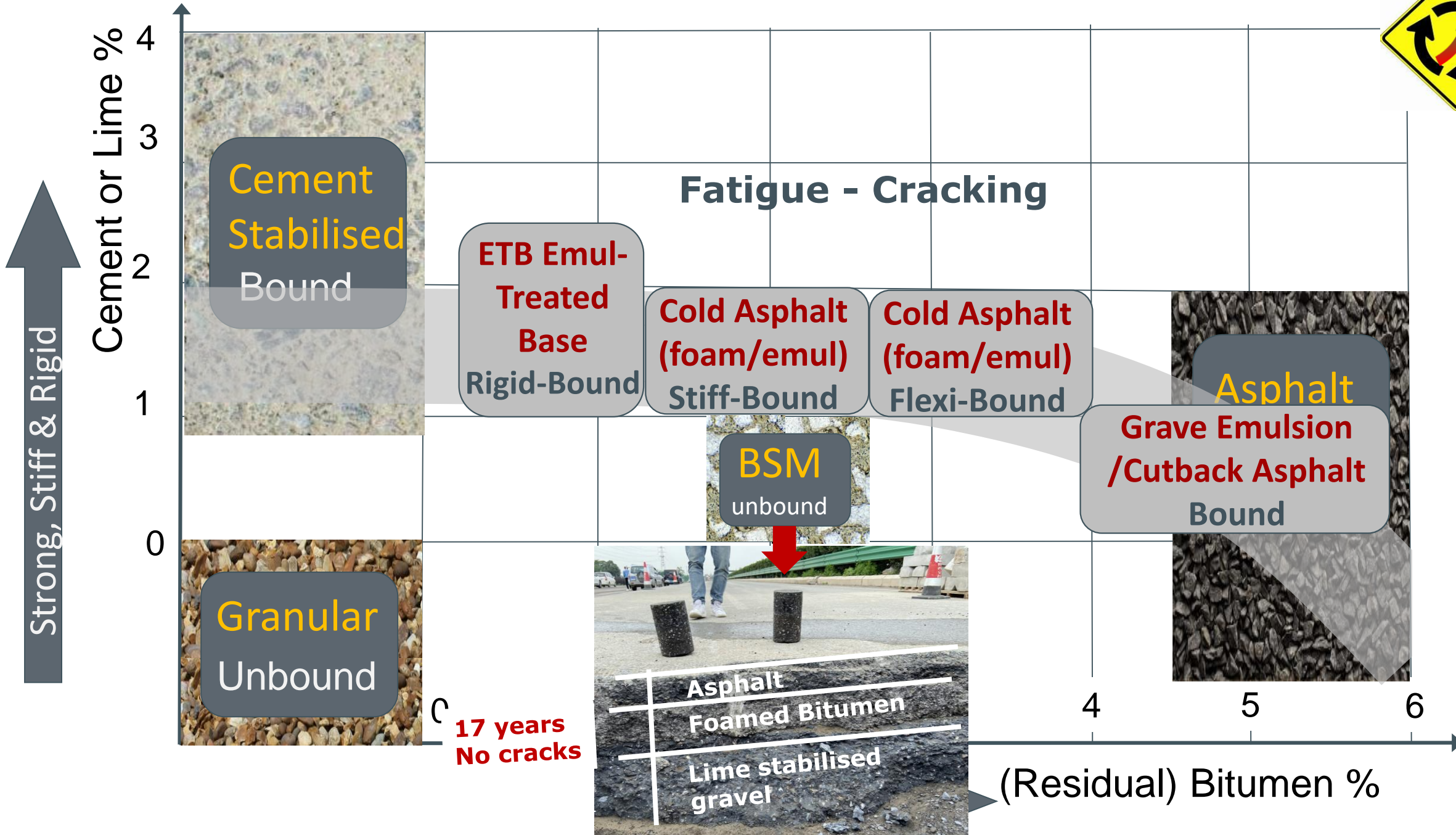


Top View

# PAVEMENT MATERIALS



# ALTERNATIVE MATERIALS



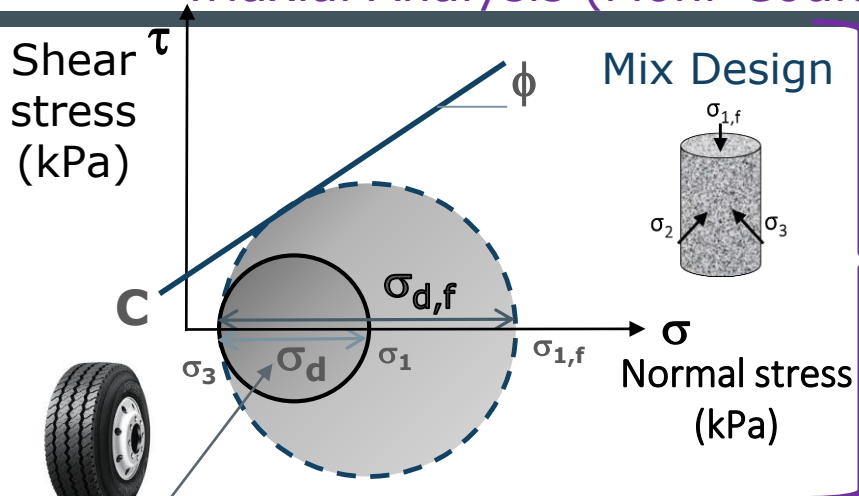
17 years  
No cracks



(Residual) Bitumen %

# NEW MECHANISTIC EMPIRICAL STRUCTURAL DESIGN FUNCTION

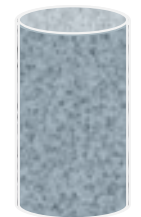
## Triaxial Analysis (Mohr Coulomb)



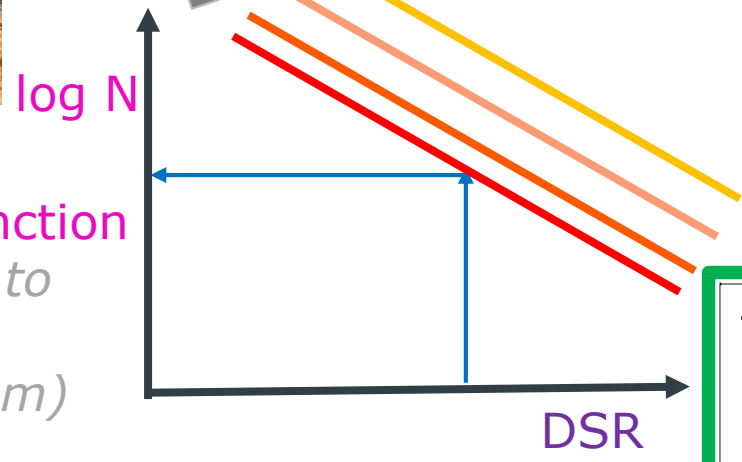
$$P_{MDD} = \% MDD$$



Retained Cohesion



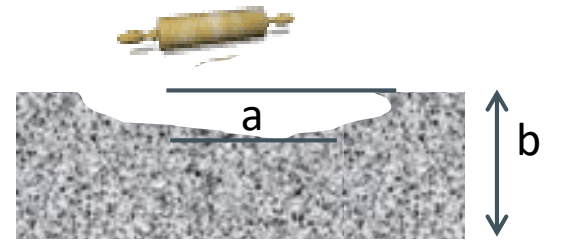
$$\log N = A - 57.286(DSR)^3 + 0.0009159(P_{MDD} \cdot RetC)$$



Transfer Function  
(specific to failure mechanism)

Reliability	Road Category	A	Rut Limit (mm)
95%	A	1.71113	10
90%	B	1.79873	15
80%	C	1.88733	20
50%	D	2.00443	25

Plastic Strain % (a/b)  
Assumed 10%



After (Bierman, Stell Univ)

# Closing the Loop

Training & Calibrating



Mix Design?



Specifications?

Classification?

Structural Performance?

Technology Challenges



Projects



Acquire knowledge

Implement

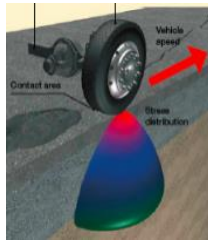
**Cold Recycling**  
*Circular Economy*



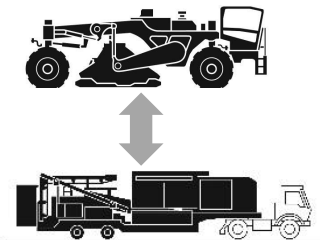
Technology Development



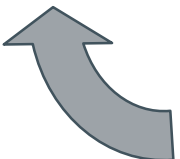
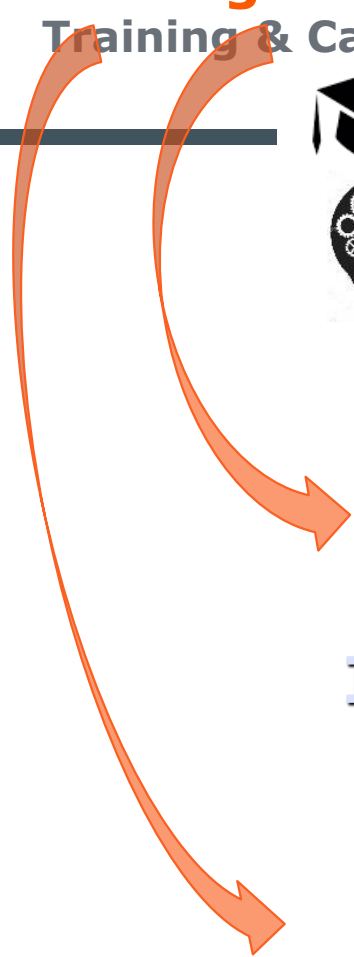
Lab Preps



Design Models



Construction





## GLOBAL SOLUTIONS



- **Recycling:** reduce Energy and Emissions
- Revolution of **Materials:** RAP up to 100%, Recycled Concrete in sub-base
- **Test Methods:** Compaction, QA, Triaxials
- **Design:** Mix to Structural Design
- **Implementation:** 100% RAP & RCA, Select Appropriate Recyclers, Quality Assurance



# MMMMMmmm Implementation

