



# Hot Recycling of Bituminous Mixtures

# Hot recycling

## Step 1



RAP



Processing



Binder content

## Step 2



Extraction and recovery

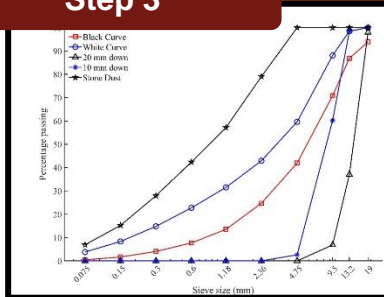


Blending studies

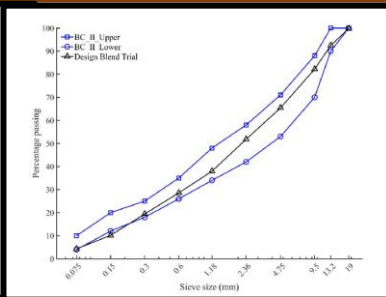


Fresh binder grade

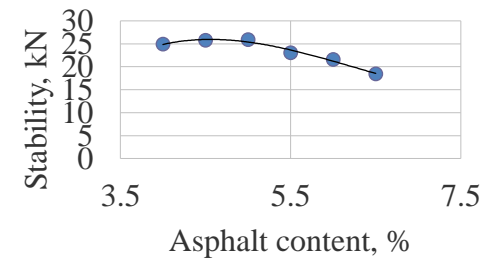
## Step 3



Design of target gradation



Marshall sample



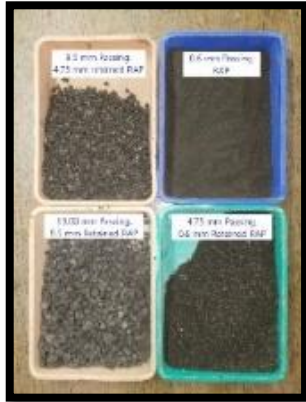
Optimum binder



# Cold Recycling of Bituminous Mixtures

# Cold recycling

## Constituents



RAP



Fresh Aggregate



Cement



Emulsion



Wirtgen, Germany:

Foamed bitumen

## Challenges

1. Is 100 % Recycling possible?
2. Whether granular or bituminous type material?
3. Determination of material properties of cold recycled mixture?
4. Application of cold recycled mixture as a surface course material?

## Mixing and compaction



Mixing

40°C



Compaction

# Bitumen Stabilized Mixture (BSM) using foamed bitumen

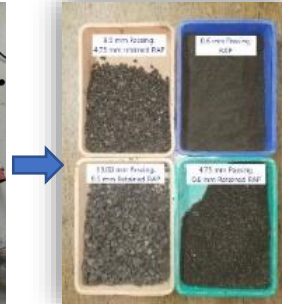


## Fabrication of BSM

Wirtgen, Germany



Foaming Equipment (WLB 10 S)



RAP

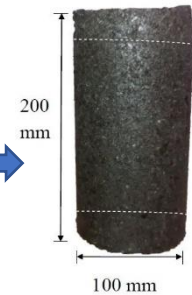
Wirtgen, Germany:



Mixing (WLB 30)

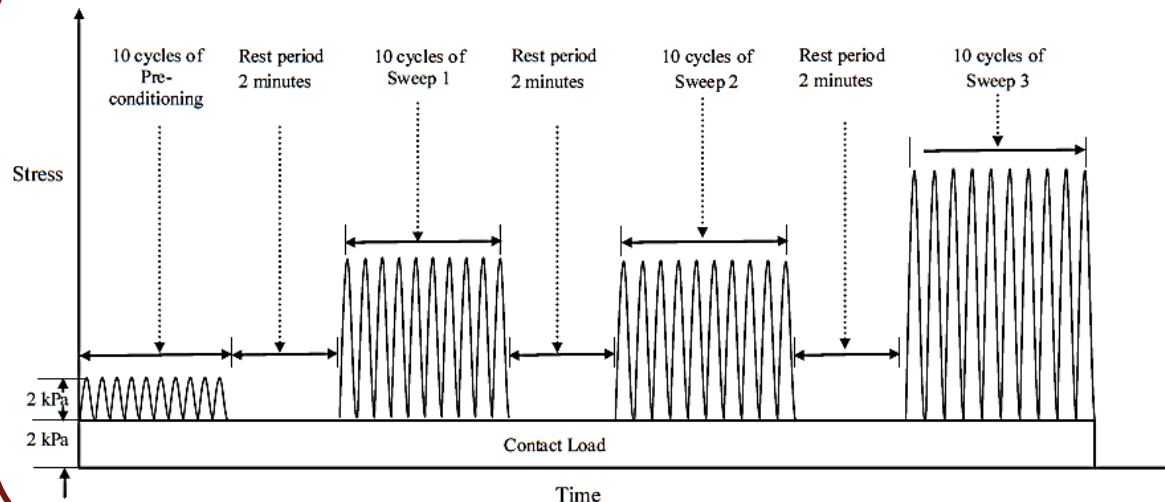


Static Compactor

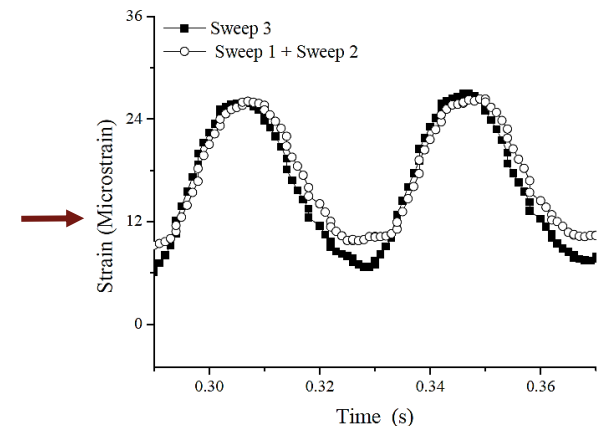


BSM Sample

## Characterization of BSM



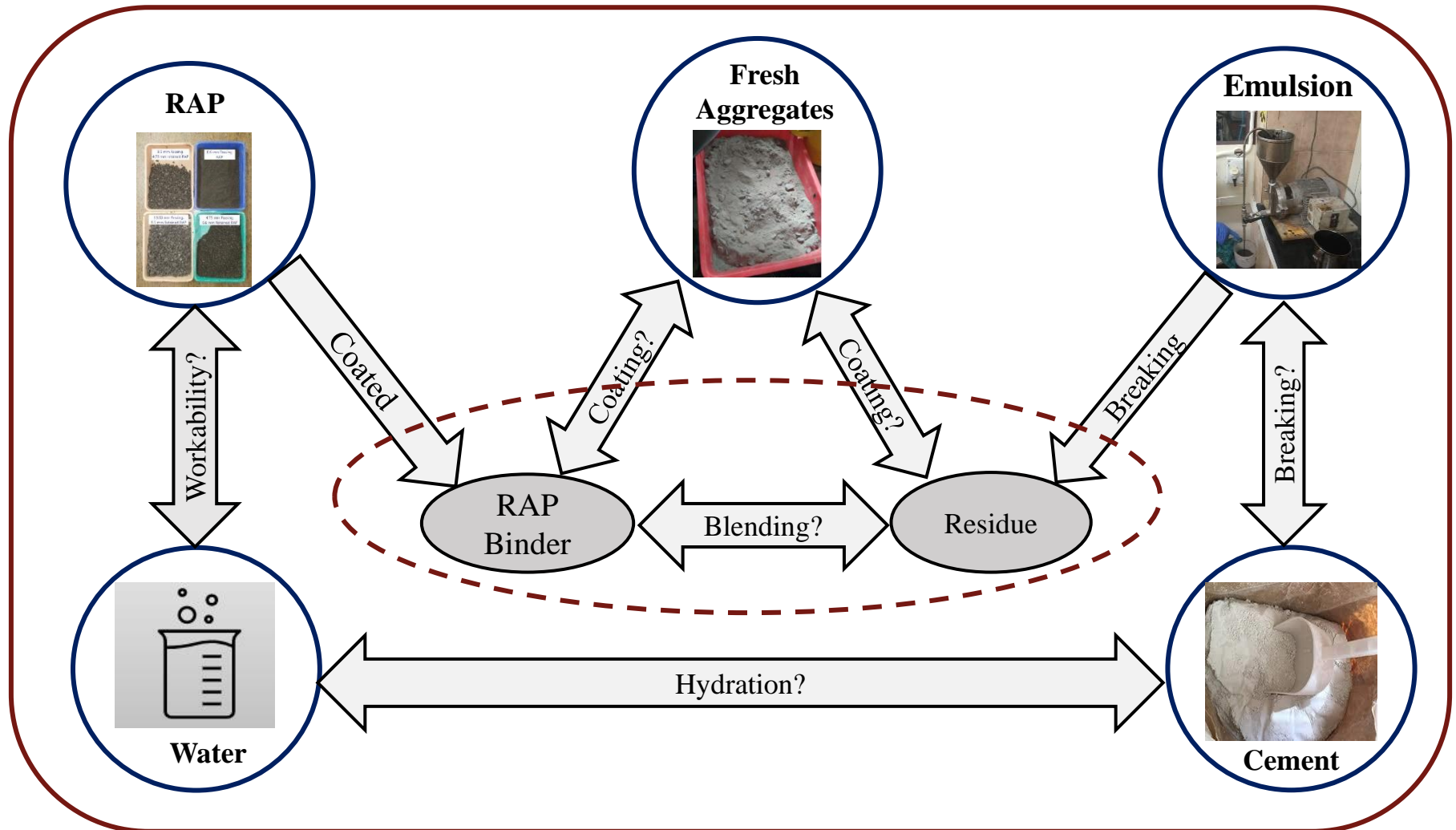
Stress Sweep test protocol



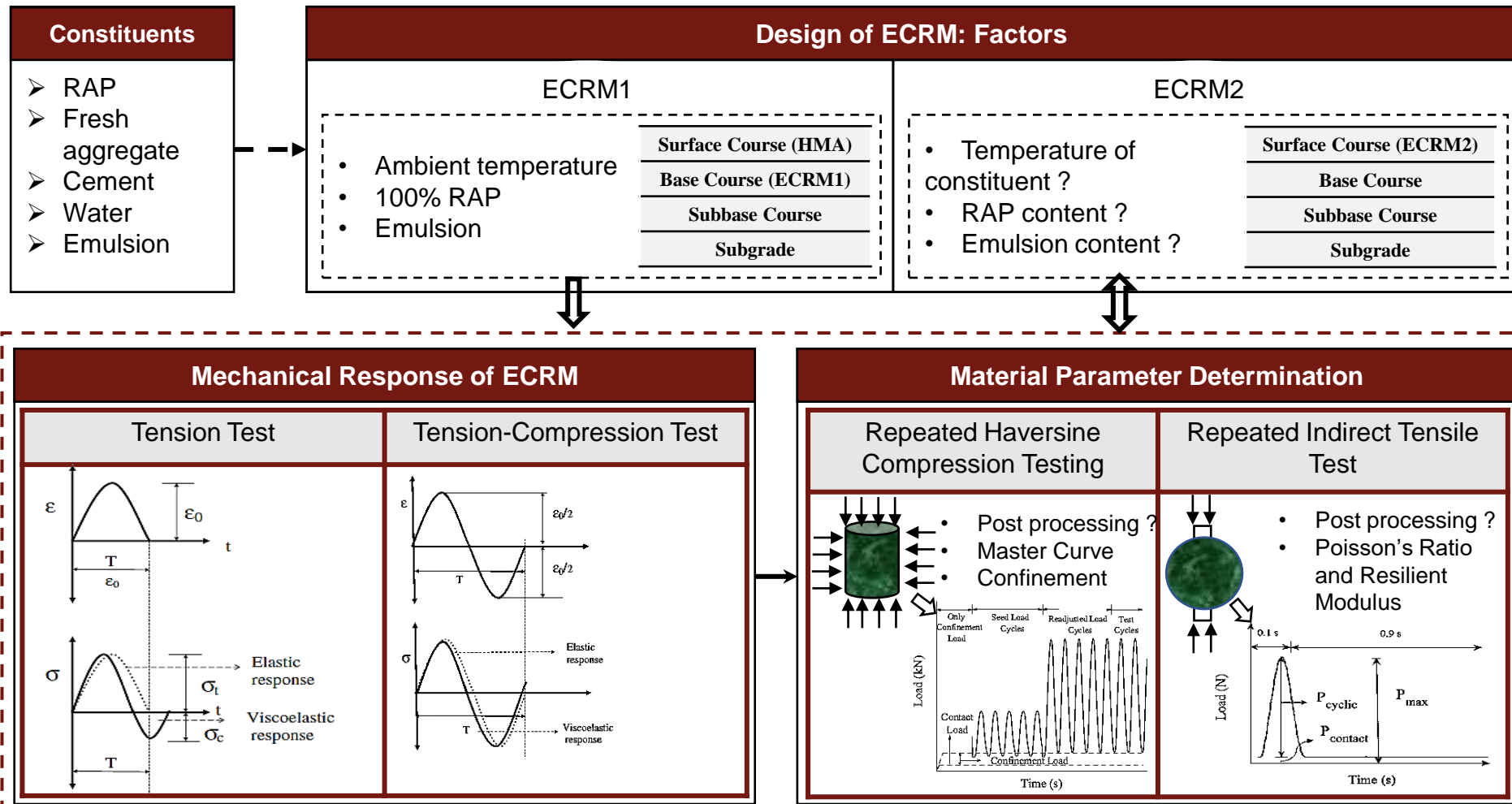
Linearity check for BSM



# Emulsified Cold Recycled Mixture (ECRM): interaction of the constituents



# Mechanical Characterization of ECRM



# Gyratory Compactor

## Working Principle

- The mechanical parts are situated in the overhead chamber of the compaction hood, enables the compactor to for the application of compaction samples with extra water content.
- Aids in the preparation and compaction of cylindrical specimens for cold mix bituminous samples.

## Application

- To determine the optimum fluid content of recycled bituminous mixes.
- Cylindrical samples can be prepared at varied levels of compaction.
- Compatibility indices can be analyzed.

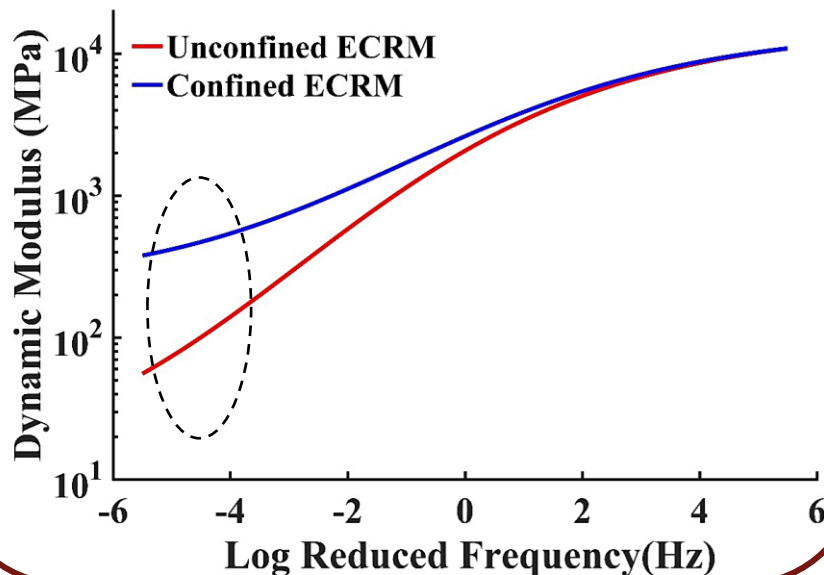


**Gyratory Compactor.  
Pine, USA**

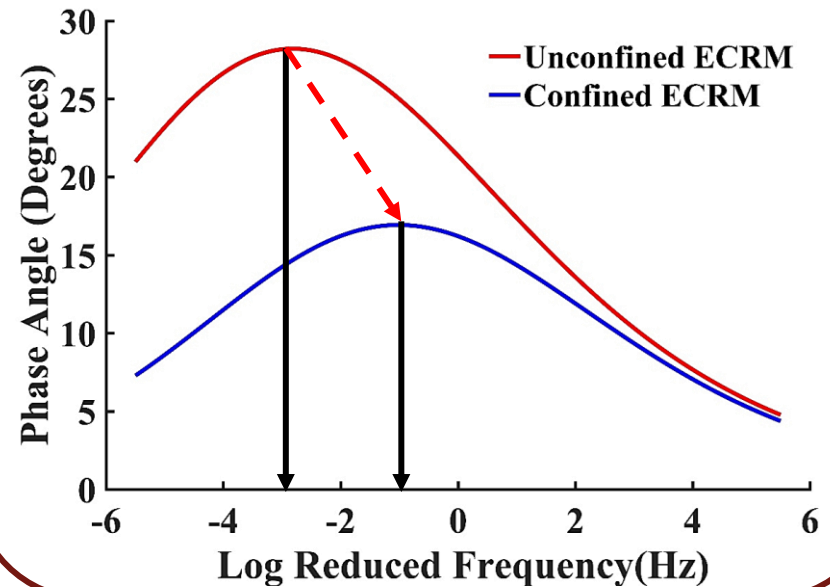


# Mechanical Response of ECRM

Dynamic Modulus Master Curve



Phase Angle Master Curve



- The influence of confinement pressure is significant at low reduced frequencies.
- Confinement pressure resulted in an increase in dynamic modulus and a decrease in the peak of the phase angle master curve.
- The increasing and decreasing trend of phase angle master curve indicates the viscoelastic response of ECRM.



# **Recycled Asphalt Mixture in Concrete Pavement**

# Valorisation of RAP in concrete Pavement



**Flexible Pavement**



**Reclamation of Pavement**



**RAP**



**Coarse RAP**

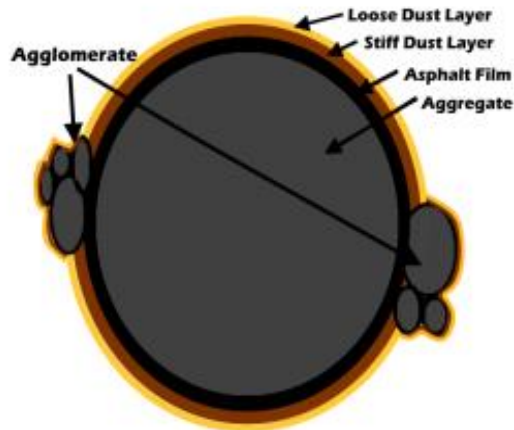


**Fine RAP**



**Concrete Pavement**

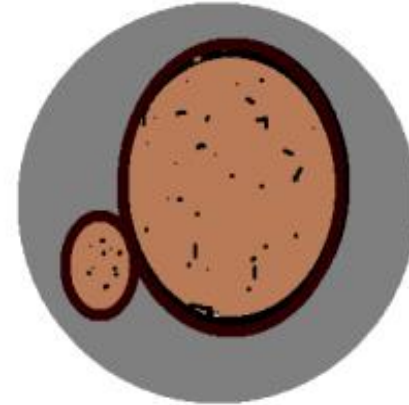
# Effect of Unprocessed RAP On Fresh Properties



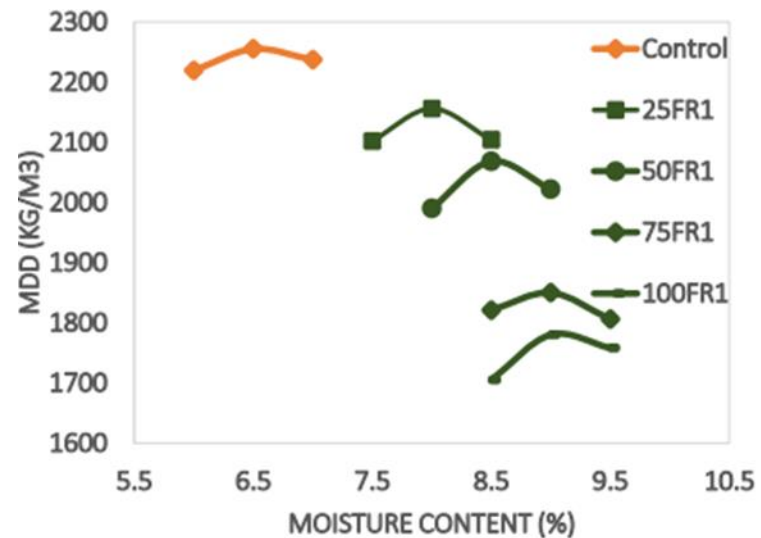
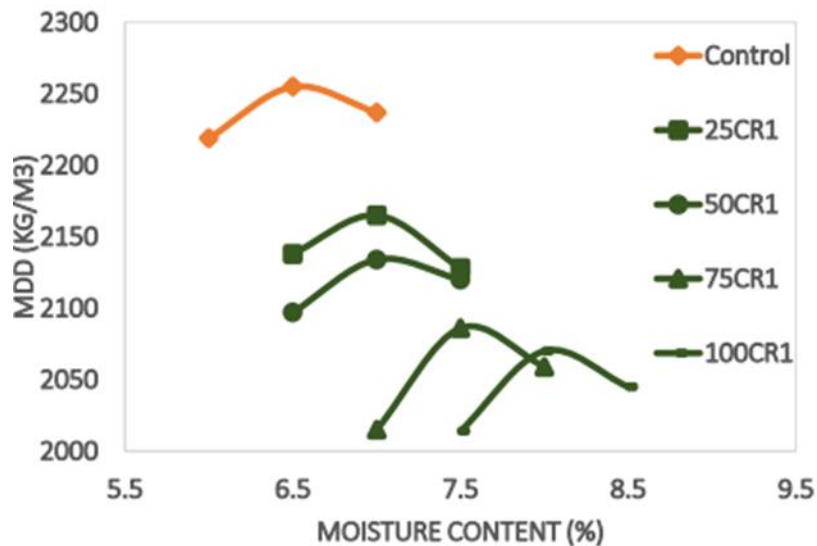
Coarse Fraction



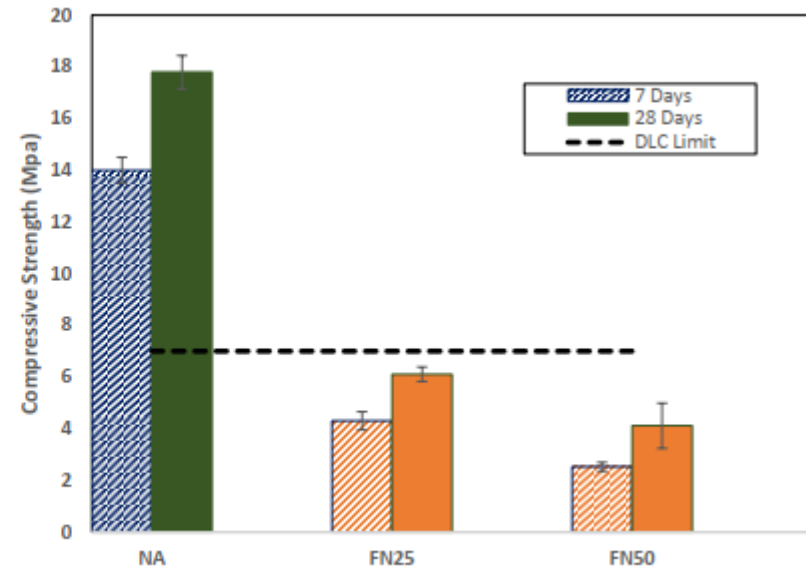
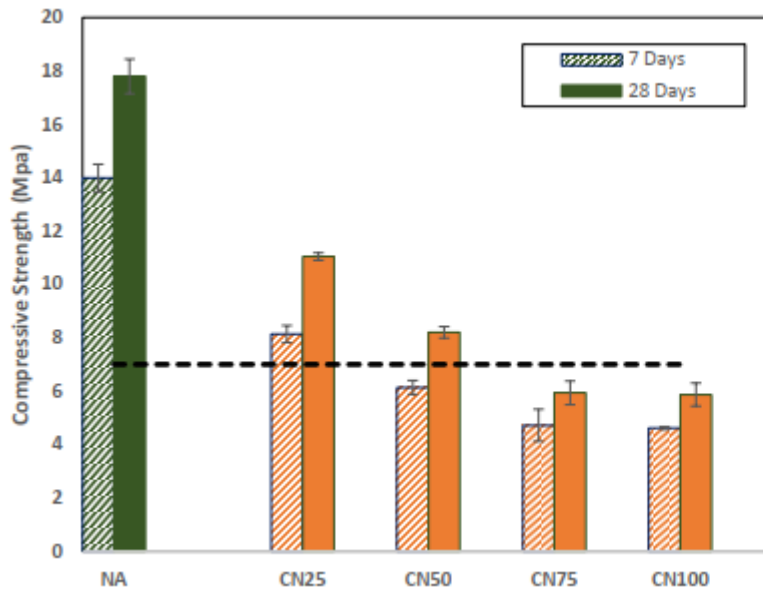
Agglomerated Particles



RAP-Concrete



# Effect of Unprocessed RAP On Compressive Strength

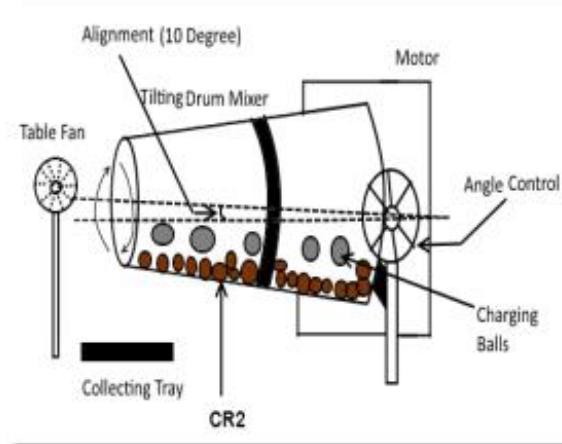


## Attributions;

1. Asphalt film: Hindrance in formation of bonding
2. Agglomerates : Voids in the mixes
3. Lack of fines: Poor cement paste
4. Lower MDD: Lower density fresh mixes will achieve less dense structure



# Addressable Measure To Improve the Properties Of RAP





# Addressable Measure To Improve the Properties Of RAP



Coarse RAP2 (CR2)



Washed CR2 (WCR2)



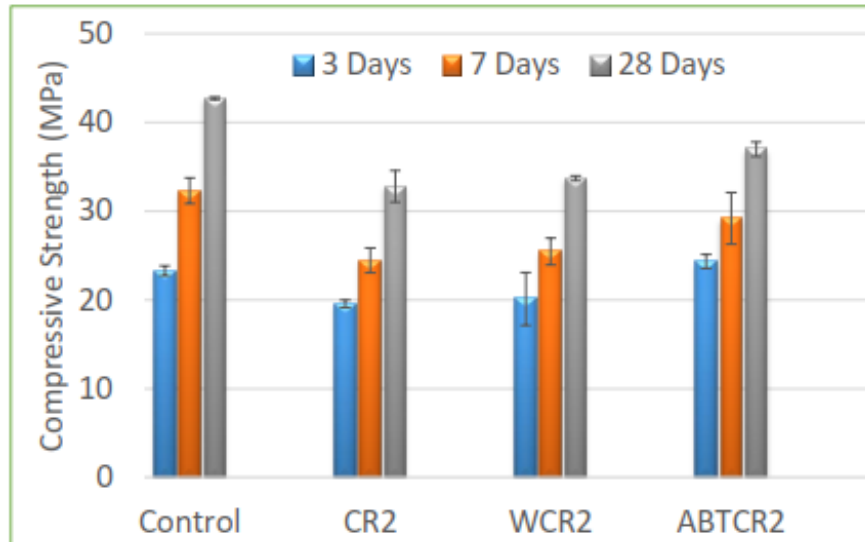
Beneficiated CR2 (ABTCR2)

Property	CR2	WCR2	ABTCR2	CNA
Bulk Specific Gravity	2.49	2.50	<b>2.62</b>	<b>2.65</b>
Water Absorption (%)	<b>1.9</b>	0.63	<b>0.45</b>	0.7
Aggregate Impact Value (%)	13	13	12	16
Aggregate Crushing Value (%)	16	11	17	22
Loss Angeles Abrasion (%)	20	18	16.3	23
Elongation Index (%)	13	12	11	14
Flakiness Index (%)	17	16	15	16
Compacted Density(kg/m <sup>3</sup> )	1497	1539	<b>1599</b>	<b>1539</b>
Void Content (%)	41	37	<b>39</b>	<b>42</b>
Agglomerated Particles	<b>15.42</b>	11.2	<b>3.49</b>	-
Asphalt Content	<b>2.17</b>	1.9	<b>1.07</b>	-

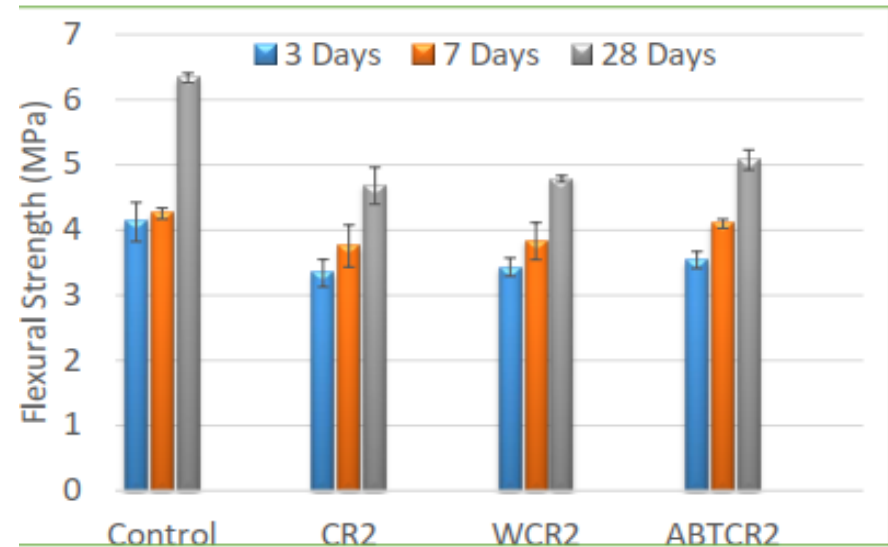
# Improved Mechanical Properties in Concrete Pavements Due To Beneficiated RAP



## Compressive Strength



## Flexural Strength



- ❑ Washing of RAP did not exhibit any benefits
- ❑ Beneficiated by AB&AT showed ~13% better strength than CR2 and WCR2 mixes
- ❑ All RAP mixes did not achieve minimum recommended compressive strength of 40 MPa for constructions of PQC pavements in India

- ❑ Washing did not improve the flexural strength ABTCR2 mix exhibited ~10% better than WCR2 & CR2 mixes.
- ❑ All the mixes achieved minimum recommended flexural strength of 4.5 MPa, however, ABTCR2 achieved recommended laboratory strength of 4.85 MPa