MARC MODIFIED ASPHALT RESEARCH CENTER

THE UNIVERSITY of WISCONSIN MADISON

# Mechanisms of Failure in Uniaxial Repeated Creep Test and the Relationship to Aggregate Packing

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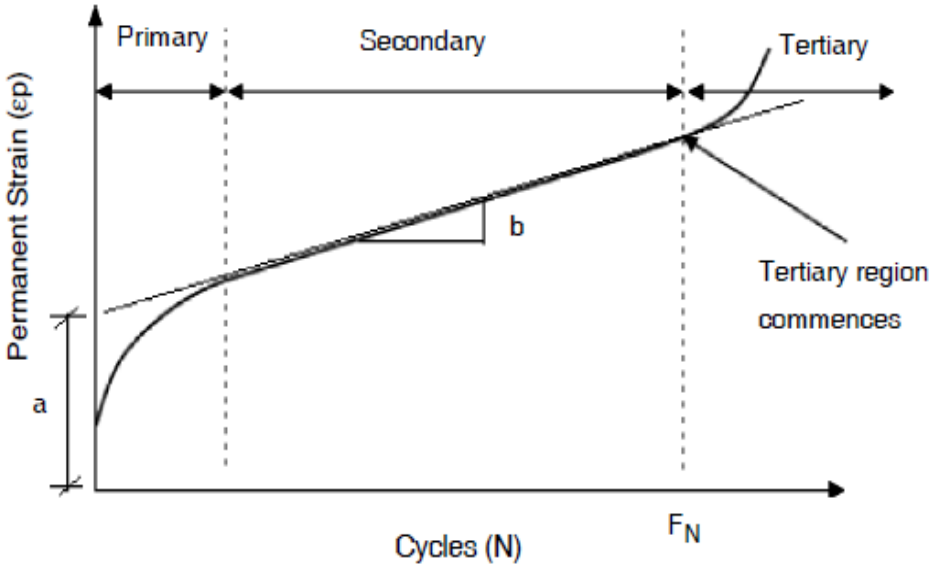
October 7, 2015
Ancona, Italy

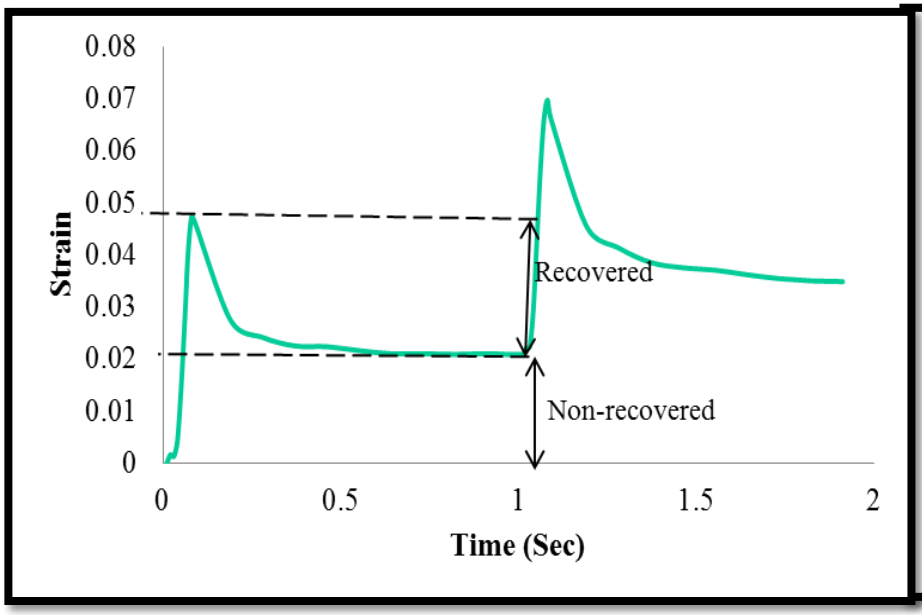
# Study Objectives

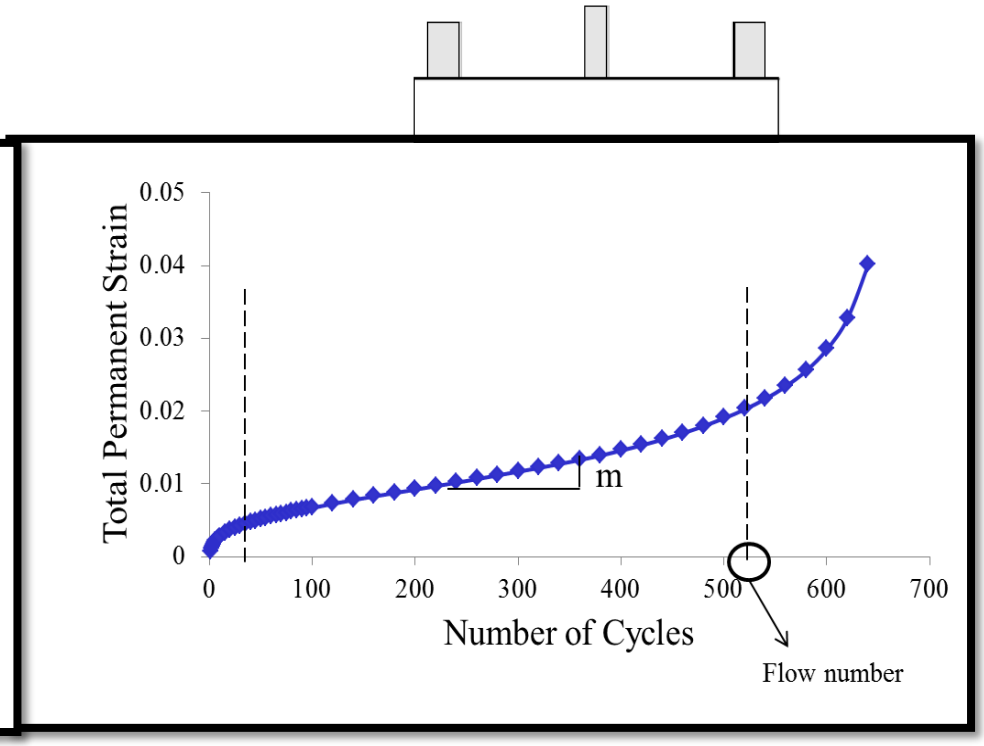
- Understand how pavement ruts evolves/develops/progresses.. Primary/Secondary / **Tertiary** .



# Introduction: Asphalt Mixture Rutting Performance and Testing

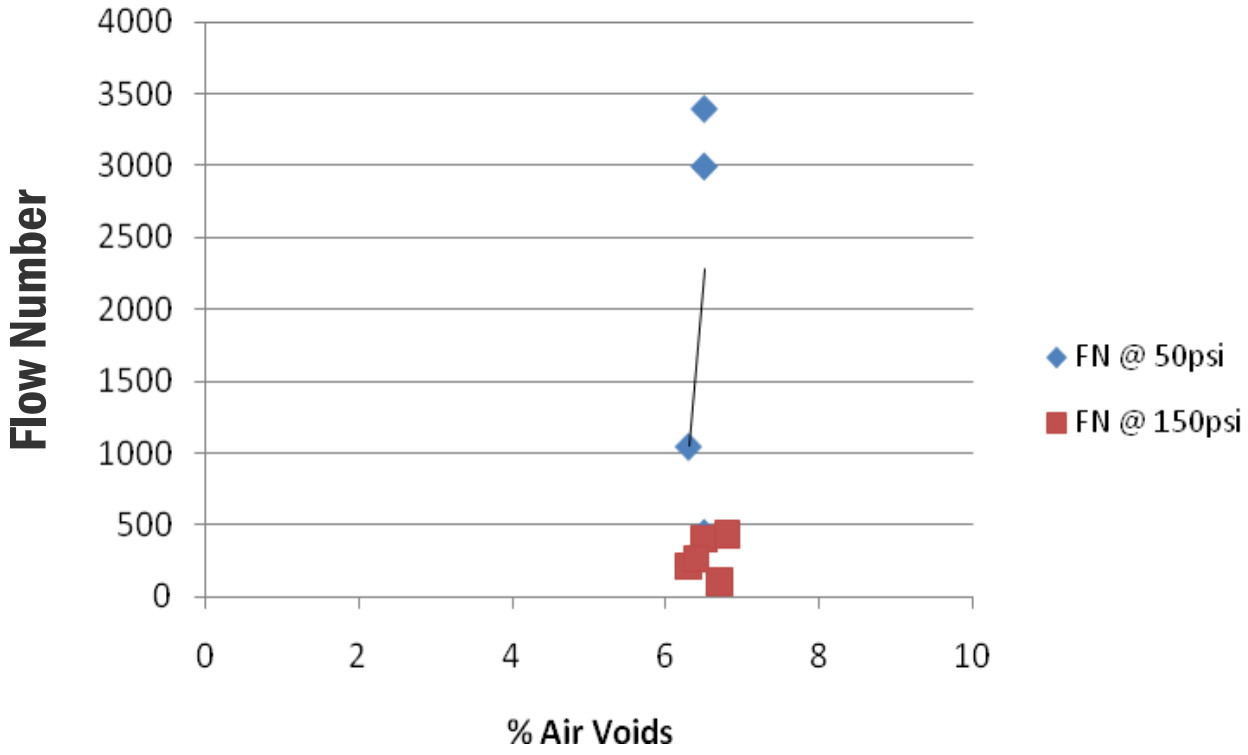
- **Rutting: Due to increasing number of heavy trucks**
  - **Densification**
  - **Shearing Deformation**



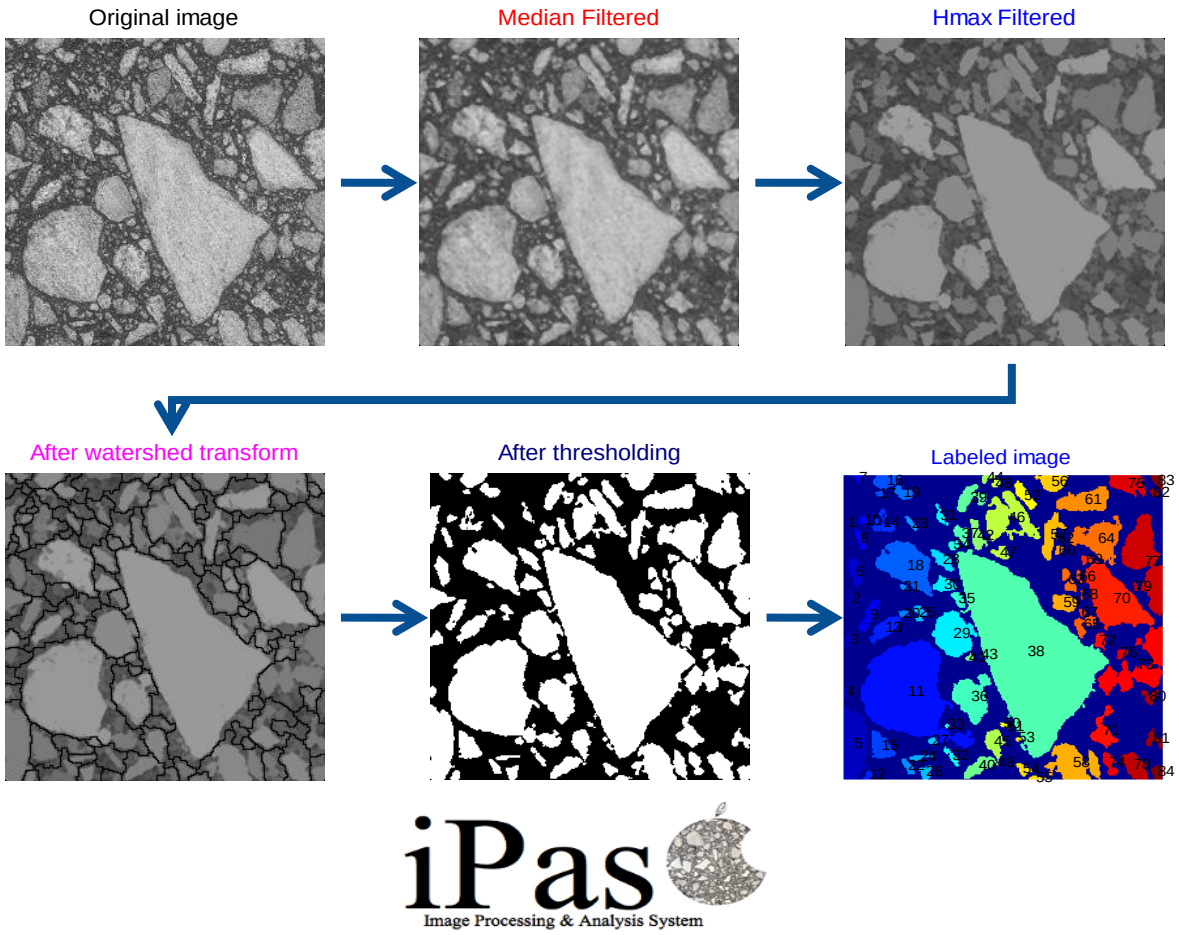



# Is Density Important?

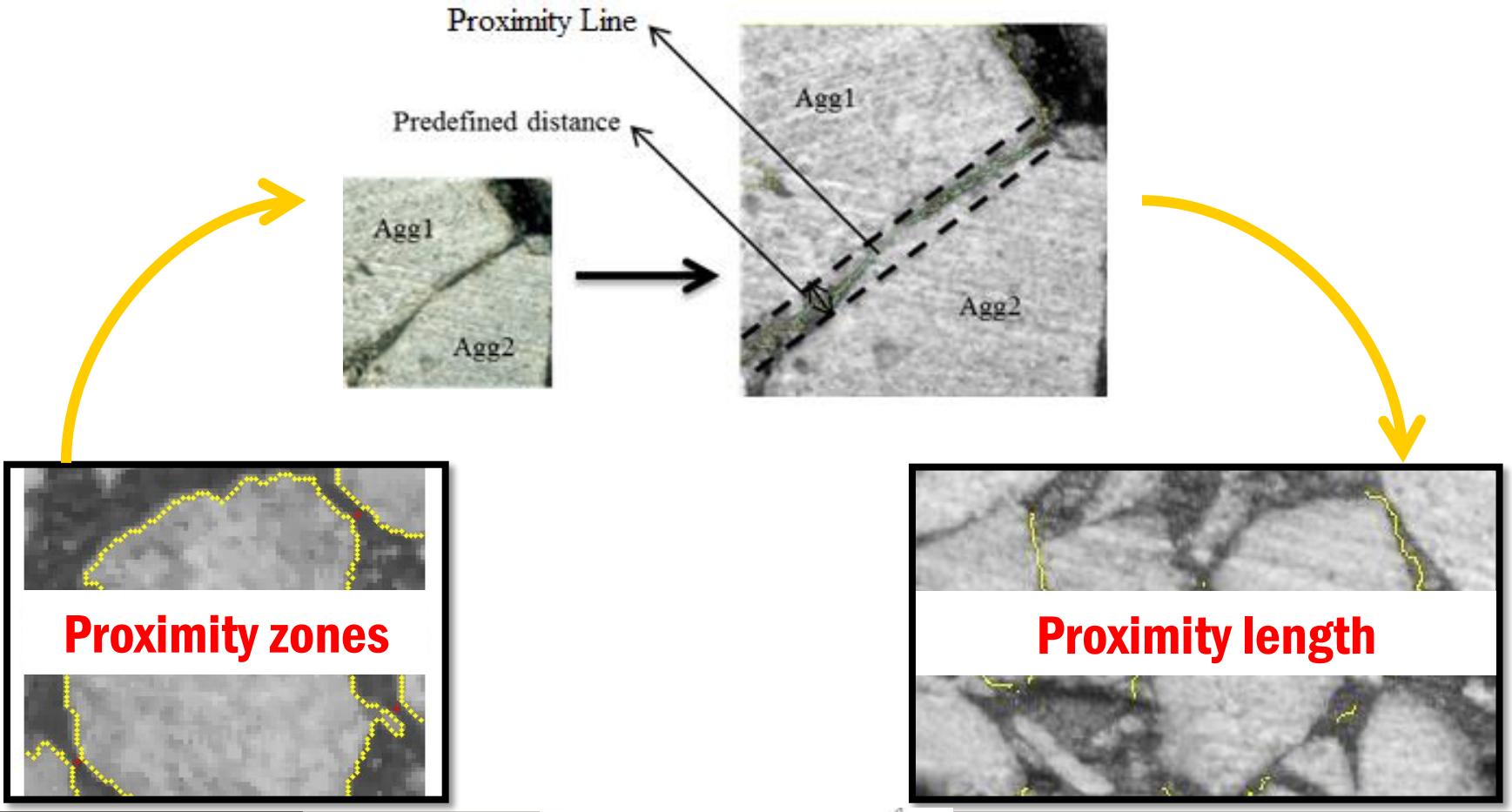
- Targeting density (AV at Ndes)as indicator of performance is not effective:
  **Mixes of the same air voids have very different performances**



# Aggregate structure characterization for asphalt mixtures

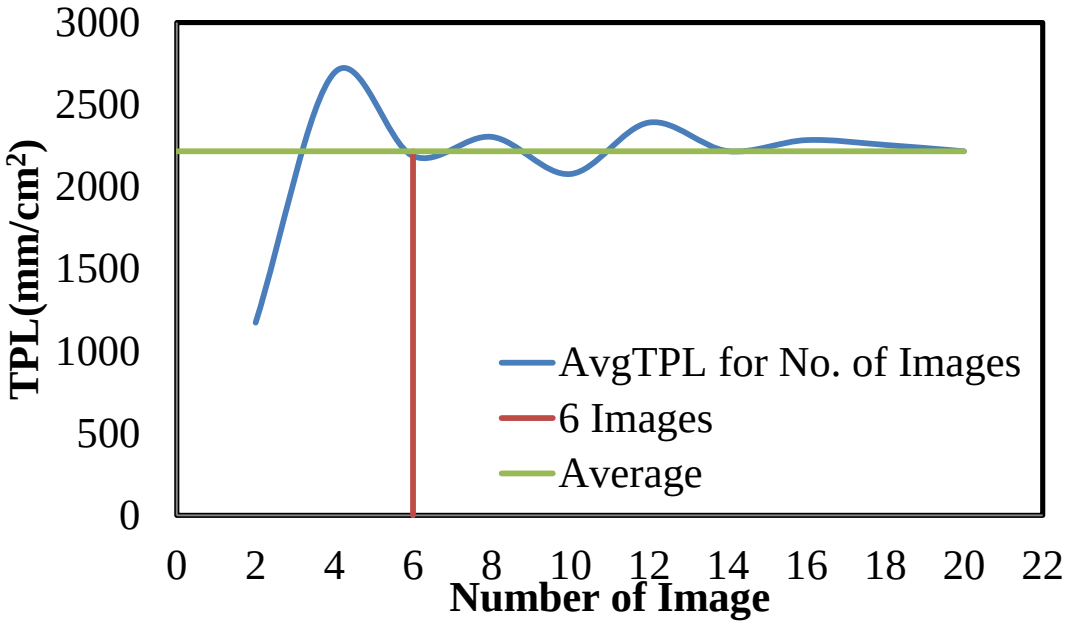


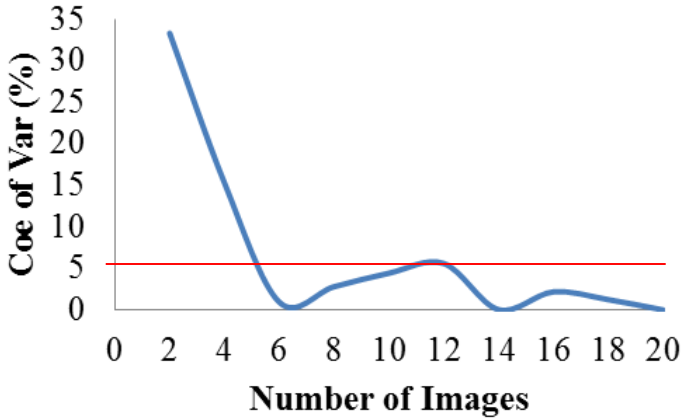
# Aggregate skeleton characterization: Total Proximatly Length



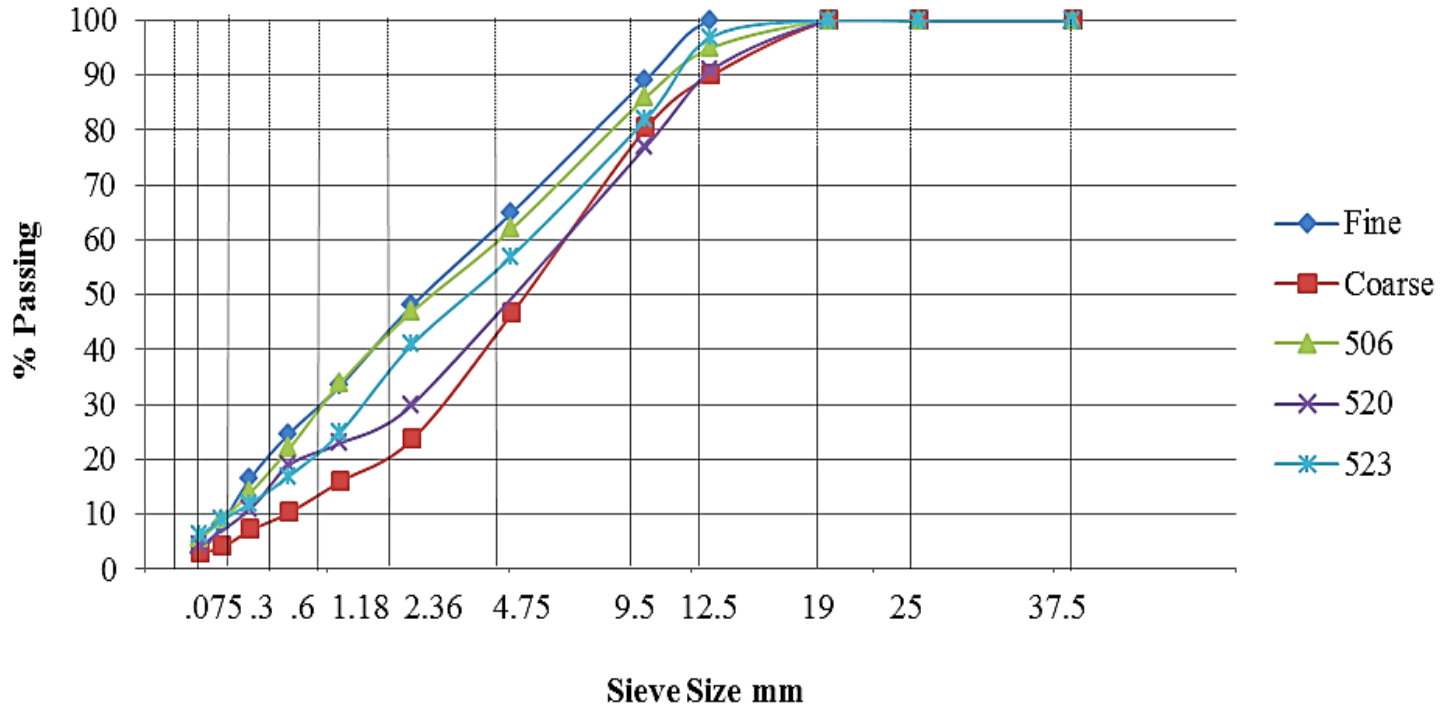
# Optimum number of sections

## *3D properties*

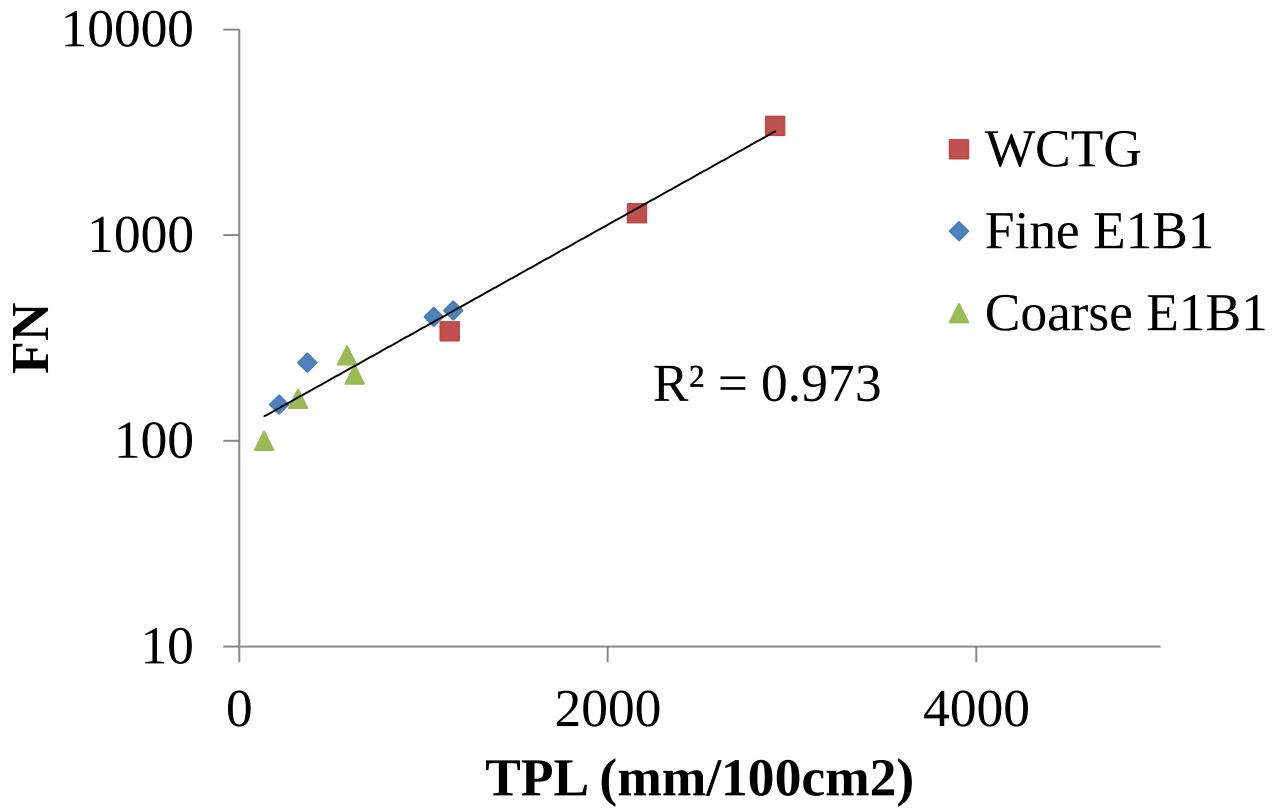



# Effect of aggregate structure on rutting: *Samples*

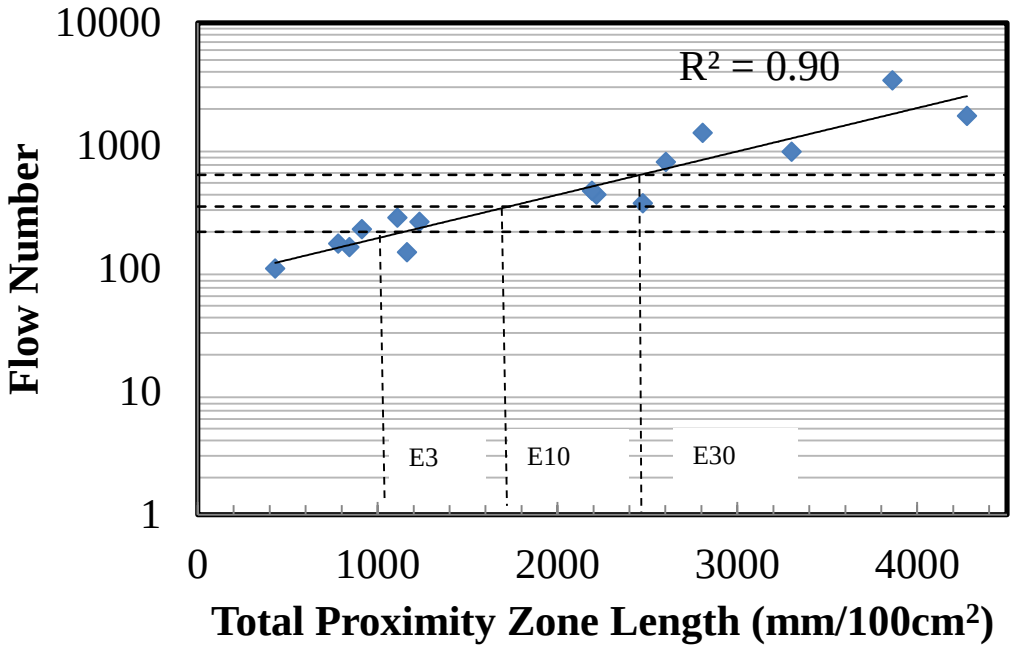


# Finding: aggregate structure is very important: TPL correlated with FN



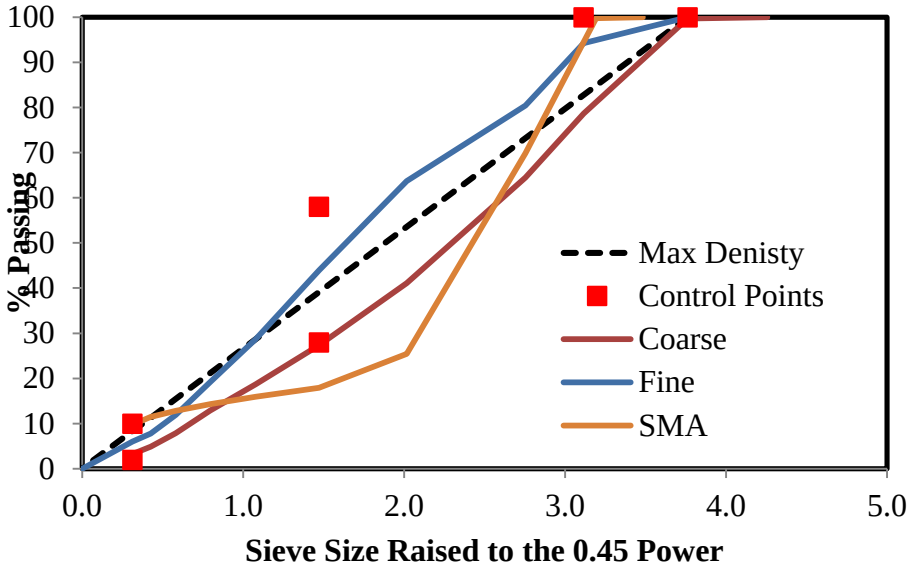
# Mechanisms of Load Transfer and Failure in Asphalt Mixtures

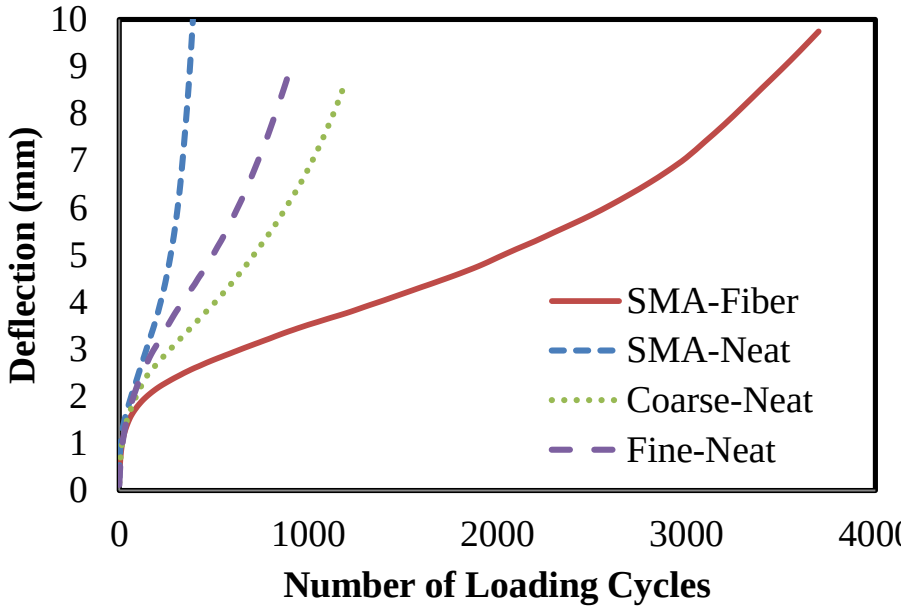
# FN-Aggregate Packing Relation



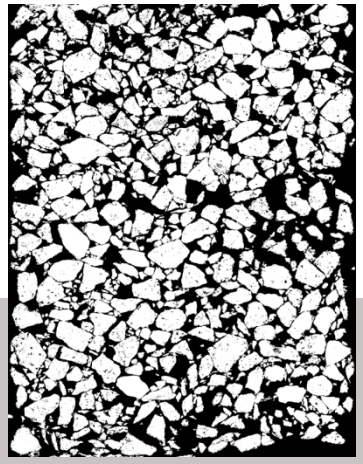

- How aggregate packing improves rutting failure in uniaxial FN?

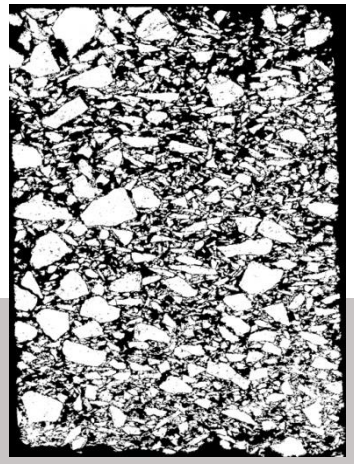
# Materials



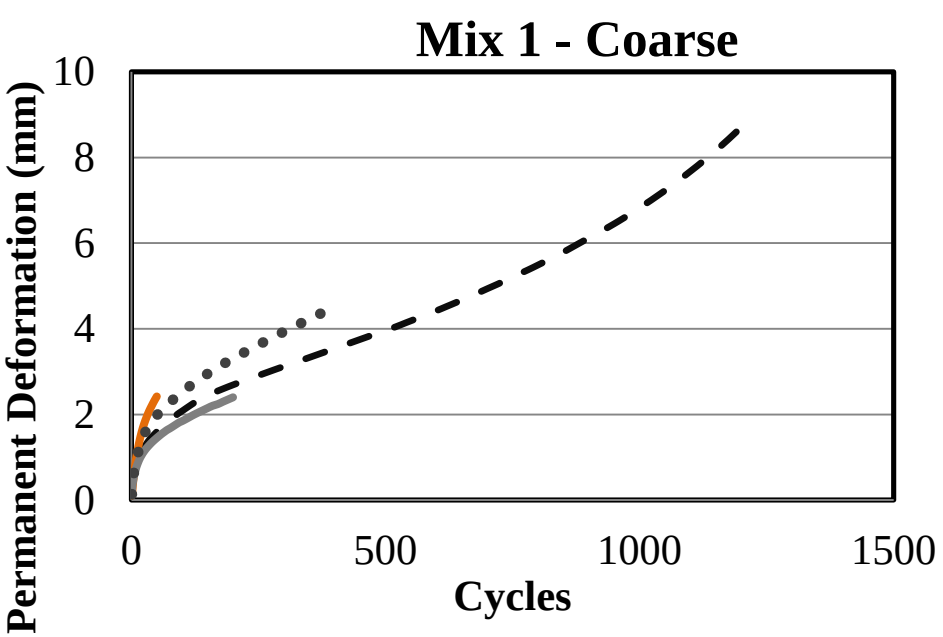

SMA

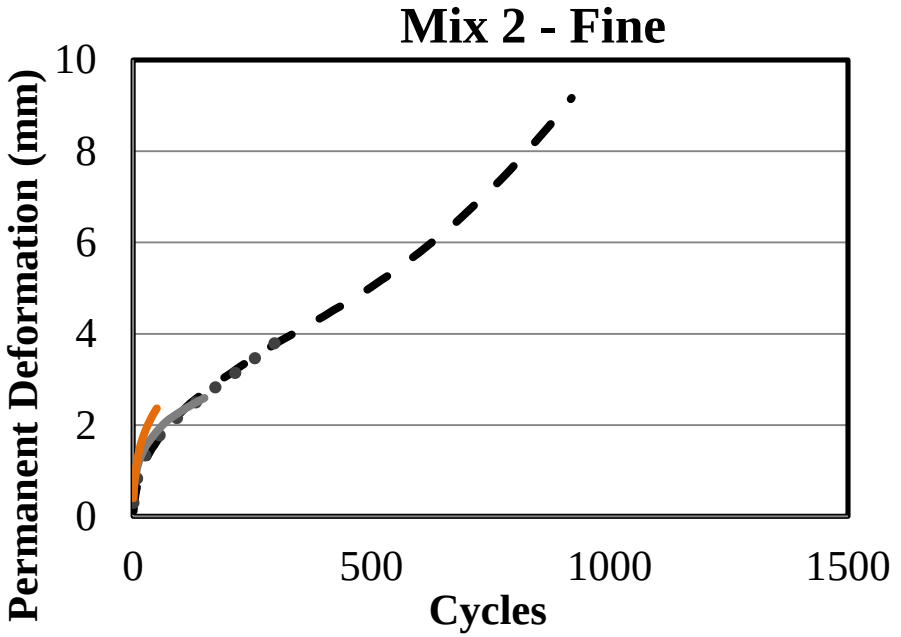




HMA

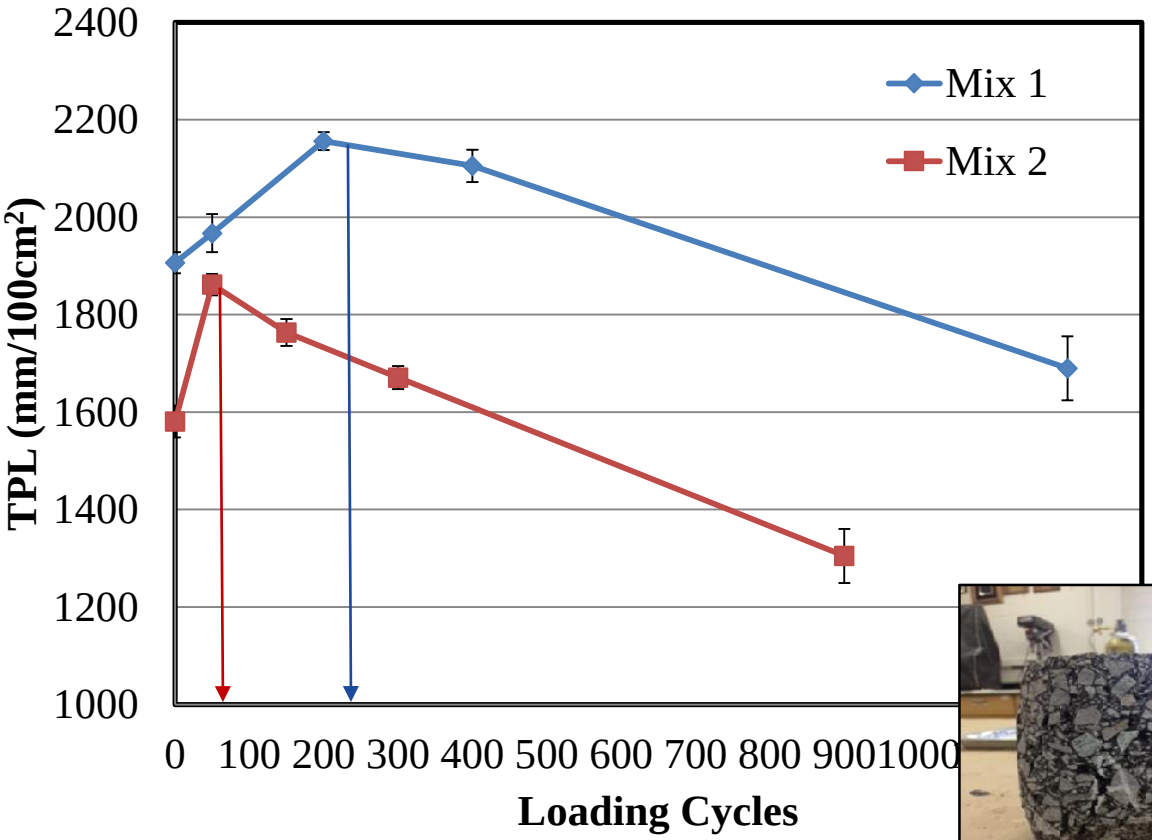
# Aggregate Packing Evolution and Density Throughout Loading :HMA

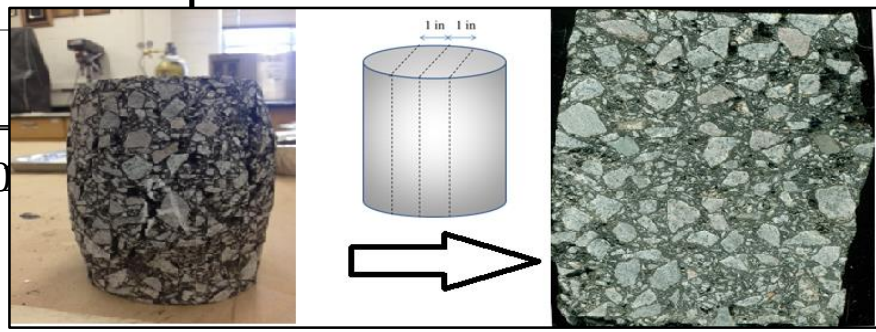



| Mix 1 | Air void % | | Mix 2 | Air void % | |
|---|---|---|---|---|---|
| Load Cycles | Before Loading | After Loading | Load Cycles | Before Loading | After Loading |
| **0** | 7.5 | - | **0** | 7.4 | - |
| **50** | 7.4 | 6.7 | **50** | 7.3 | 6.7 |
| **200** | 7.3 | 6.6 | **150** | 7.4 | 6.2 |
| **400** | 7.5 | 6.5 | **300** | 7.5 | 6.1 |
| **1200** | 7.4 | 10.3 | **920** | 7.5 | 17.2 |

# Evolution in Aggregate Packing and Density Throughout Loading



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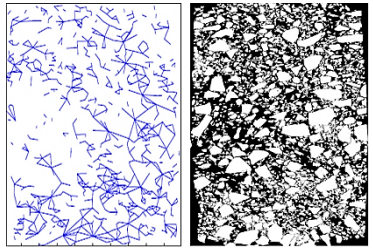
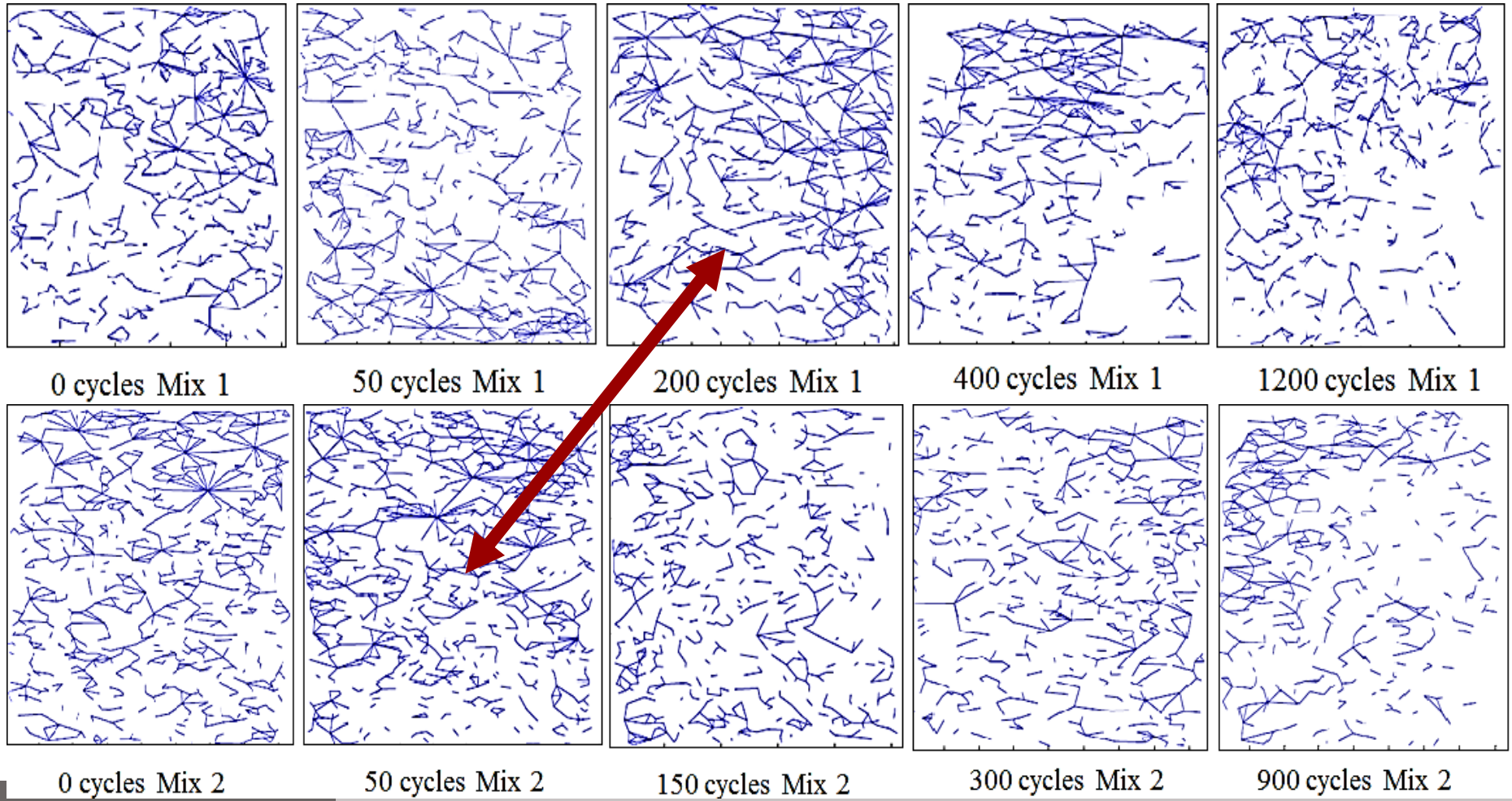


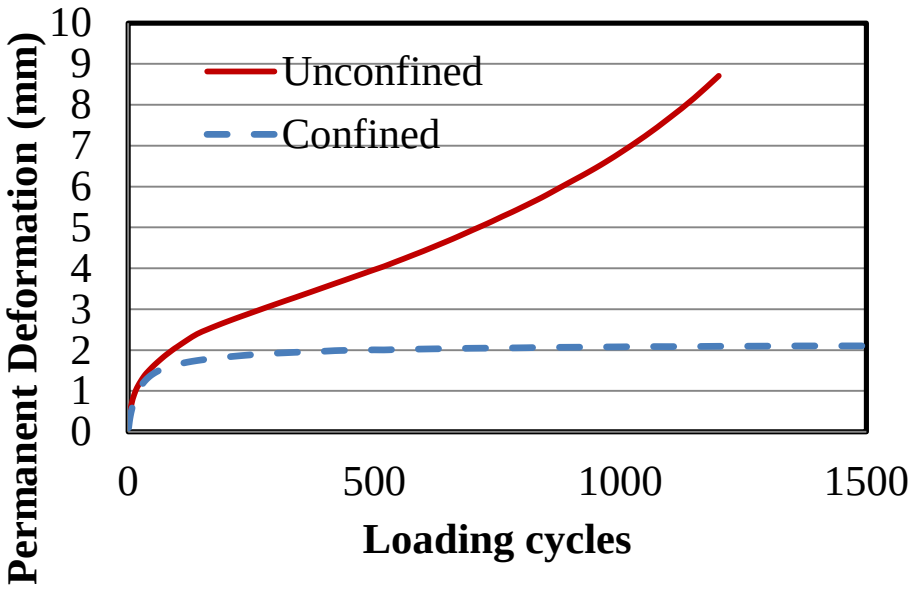


# Mechanisms of Deformation in Primary, Secondary, and Tertiary Zone

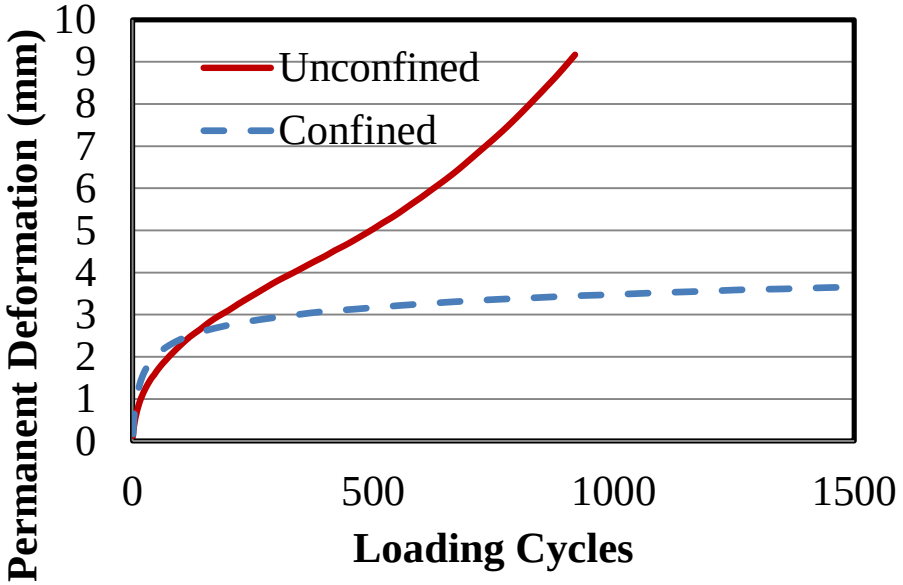
- Based on network plots, density, and visualization :
  - **Primary zone**: **Mainly densification** & increase in packing
  - **Secondary zone**: **Mainly shearing**, aggregate skeleton starts deformation along the directions that show **less confinement** (i.e. outside of sample);aggregate skeleton is still, there is no rapid deformation or failure of sample.
  - **Tertiary zone**: **High deformation** in some part of aggregate skeleton (i.e. **localized bulging of sample**)
- Higher confinement, better aggregate packing → delay tertiary zone

# Effect of High Confinement: No Tertiary flow

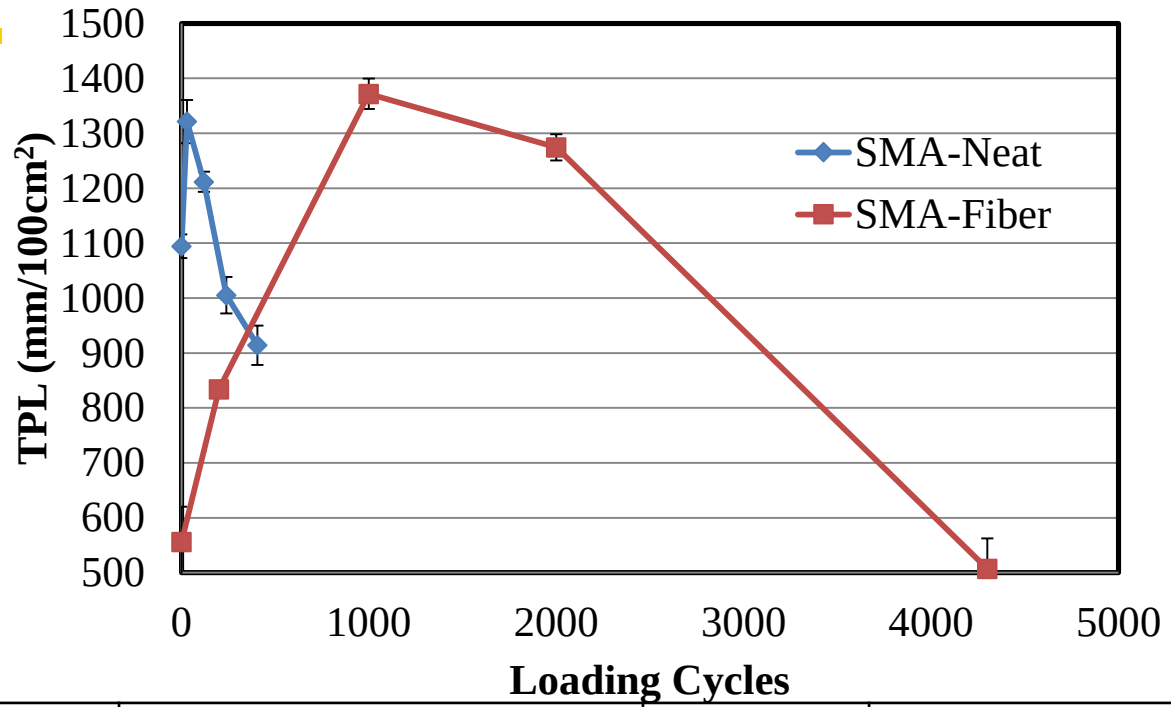
Mix 1




Mix 2



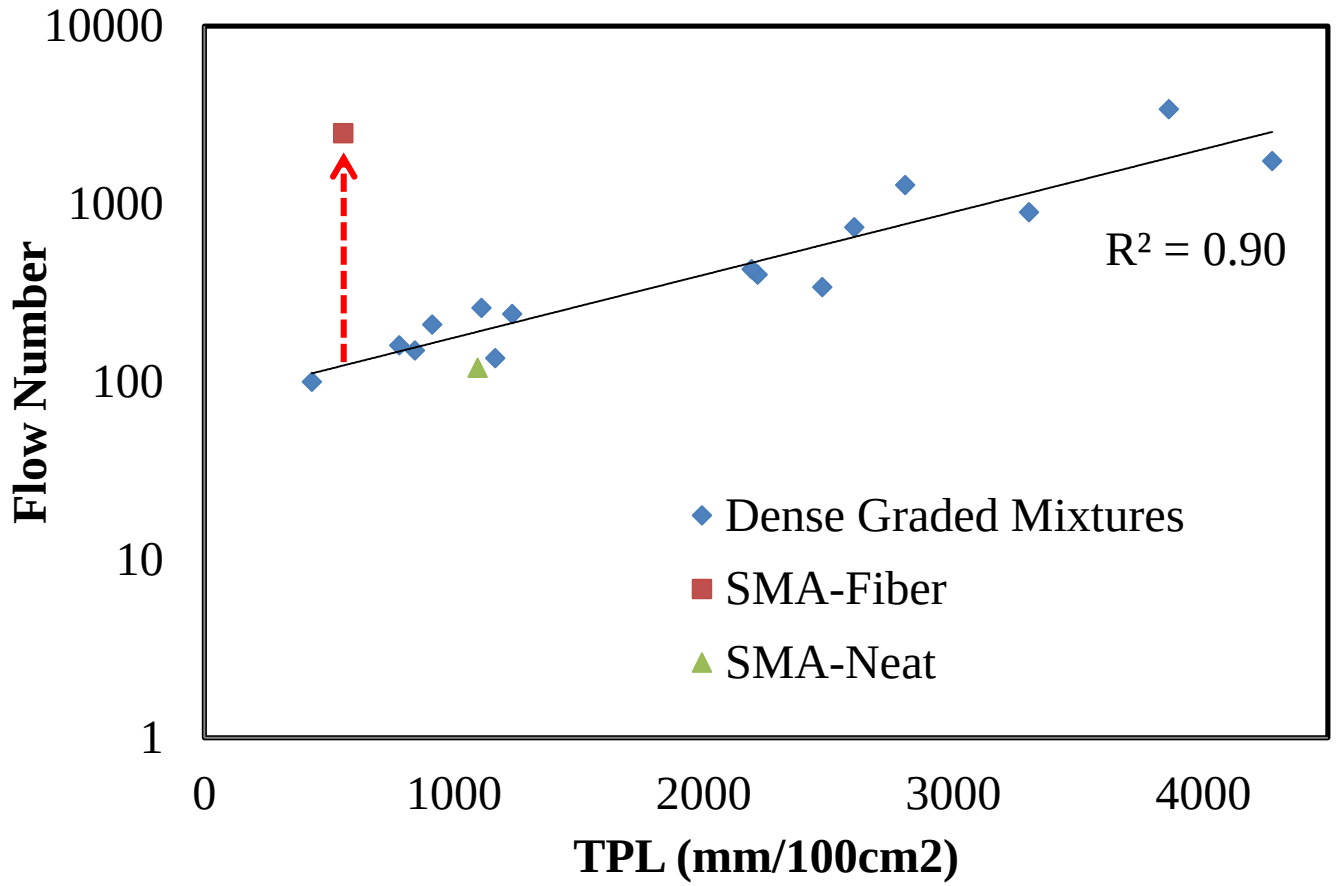
# Failure in SMA Mixture: Confinement in mastic




| SMA Neat | Air void % | | SMA Fiber | Air void % | |
|---|---|---|---|---|---|
| Load Cycles | Before Loading | After Loading | Load Cycles | Before Loading | After Loading |
| 0 | 7.2 | - | 0 | 7.0 | - |
| 30 | 7.1 | 6.2 | 200 | 7.3 | 6.1 |
| 120 | 7.5 | 5.9 | 1000 | 7.1 | 5.7 |
| 240 | 7.4 | 5.5 | 2000 | 7.5 | 5.5 |
| 405 | 7.4 | 11.4 | 4300 | 7.3 | 10.3 |

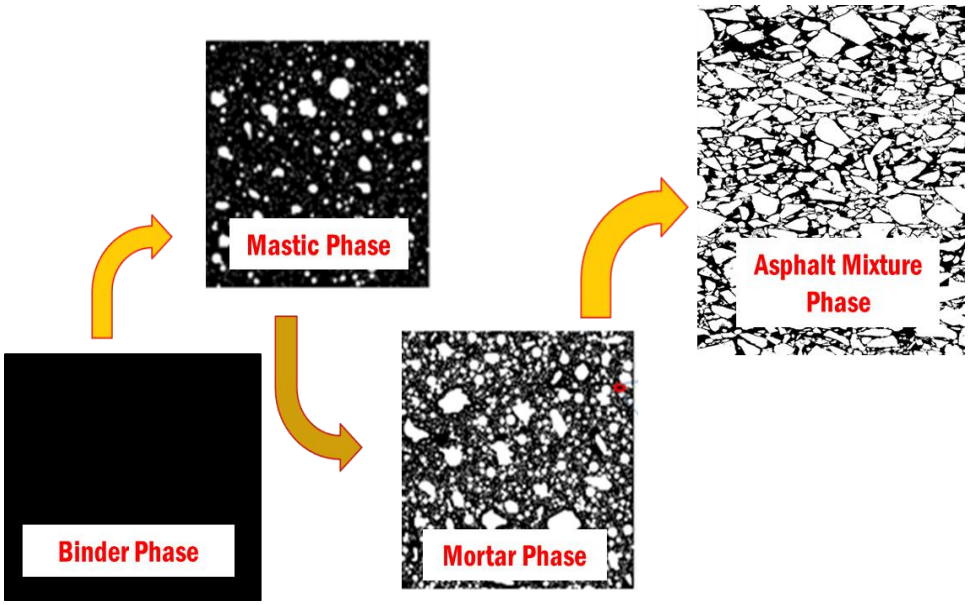
# Failure in SMA Mixture:

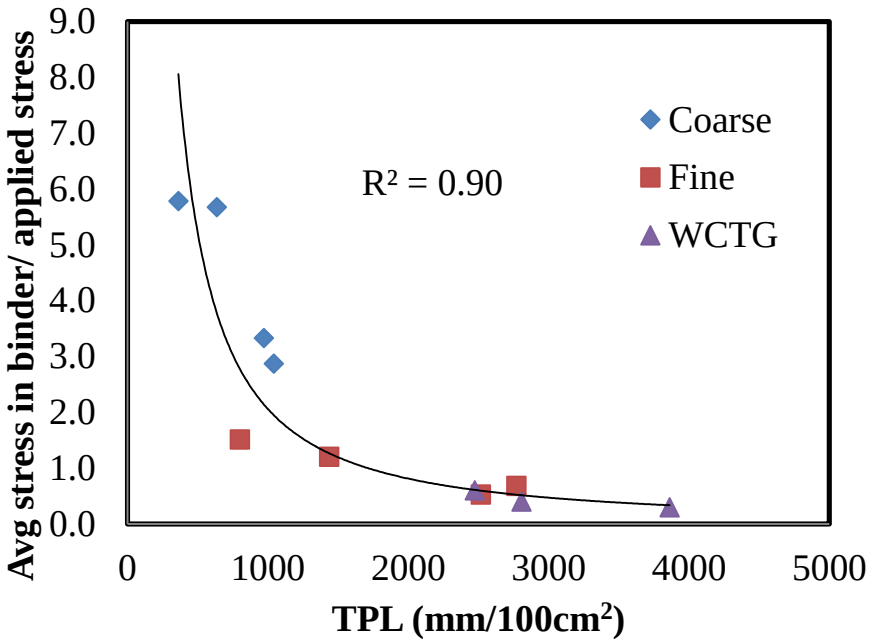
## *Unique behavior/less dependent on Skeleton*



# Effect of Aggregate Packing on Load Transfer Mechanism in AC

- Stress distribution on continuous phase
  - Multi-scale



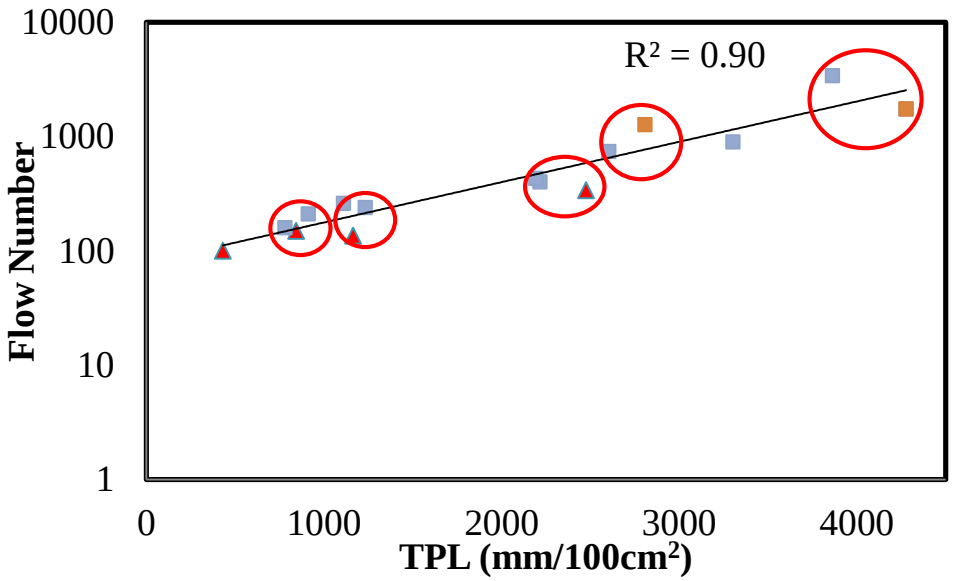


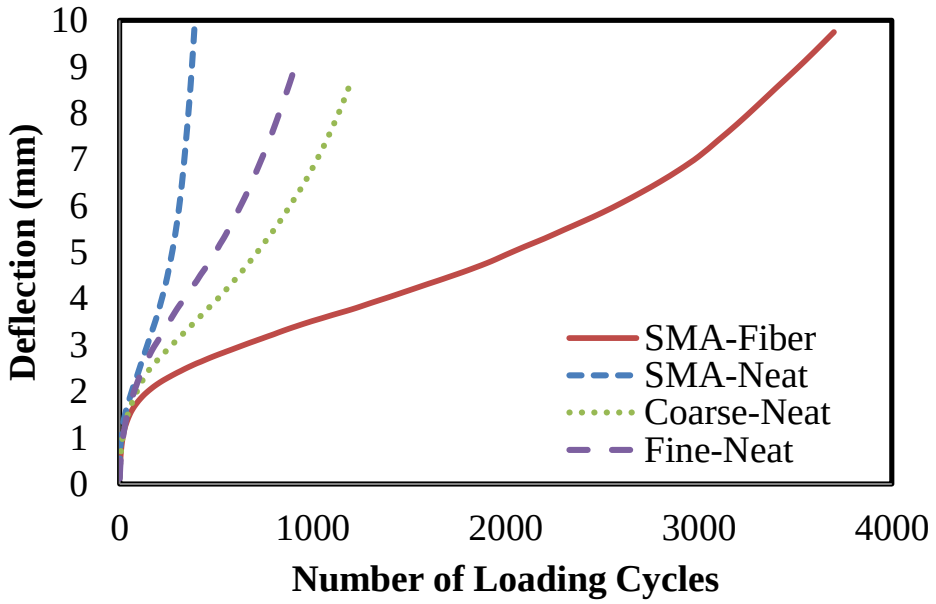

* Arshadi et al, 2013

# Which Mechanism is More Important?

**Highly packed mixtures → Aggregate stability is main mechanism**

**Lower Aggregate packing mixtures → Stress distribution is main mechanism**

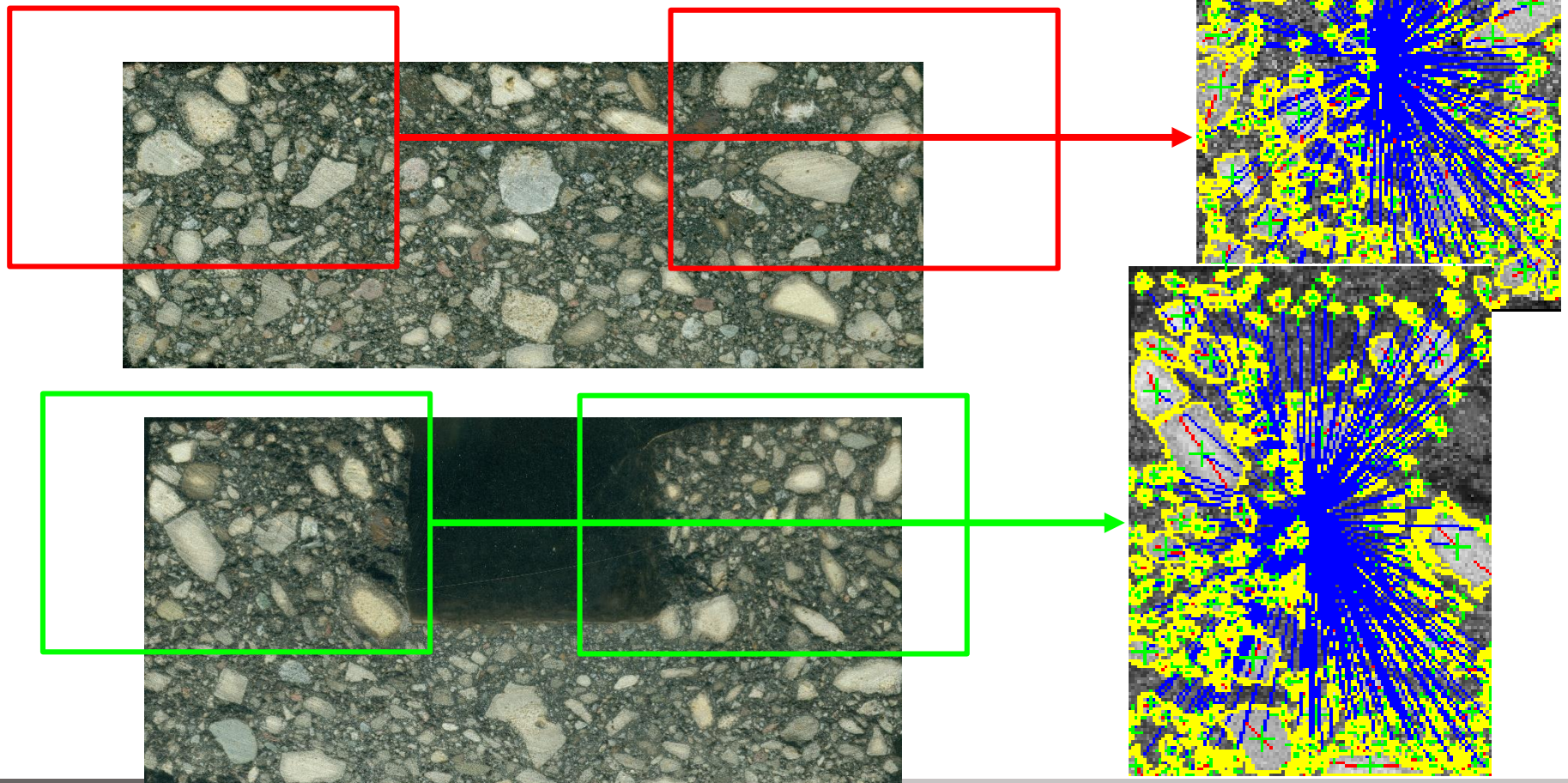


# Summary of Findings

- Load transfer mechanism includes:
  - Aggregate skeleton and
  - mastic rheology:
- Mixtures with higher packing(TPL>~2500mm/100cm$^2$) aggregate particle stability is the main mechanism.
- Confined testing showed no tertiary zone → No aggregate structure instability in confined condition
- Rutting:
  - Primary zone: Densification, increase in TPL
  - Secondary zone: TPL starts decreasing >> dilation of aggregate structure
  - Tertiary zone: Severe instability due to aggregate skeleton bulging (dilation)

# What is next ?
# Wheel Tracking



# Acknowledgements

This research was sponsored by the Asphalt Research Consortium (ARC), which is funded by FHWA and MARC partners. This support is greatly appreciated.

**Special Thanks to:**

- RILEM TG2 members and friends

# QUESTIONS?

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