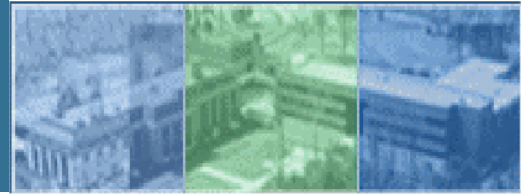


Modification of Asphalt Binders with Phosphoric Acid Mix Tests

Federal Highway Administration
The Office of Research, Development, and Technology (RD&T)
Turner-Fairbank Highway Research Center (TFHRC)
McLean, VA

PPA Workshop Minneapolis April 7-8 2009

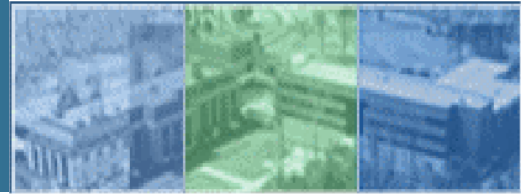




Preconceptions and Concerns about Polyphosphoric Acid

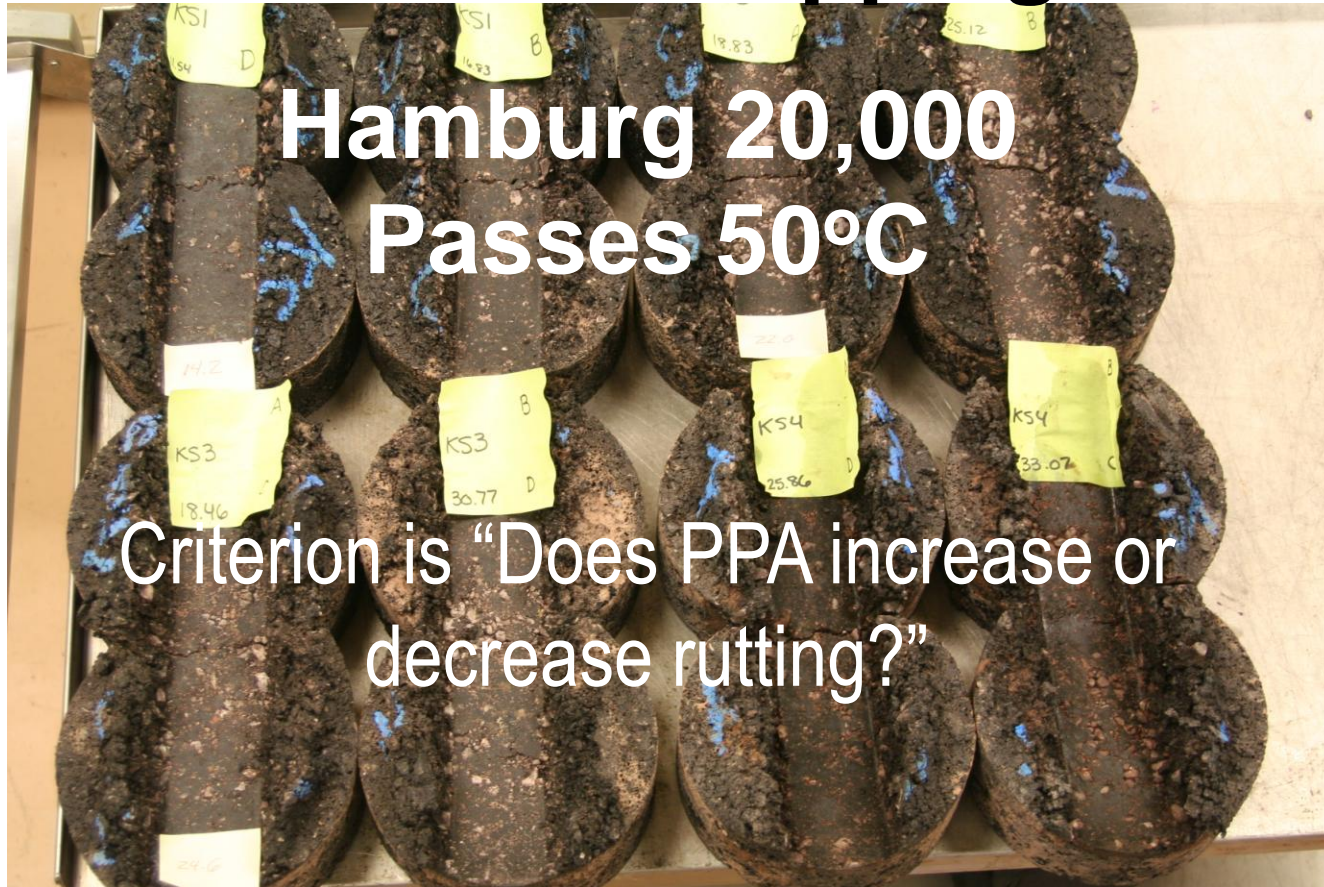
- **Use with Antistrip Additives – Depends on Aggregate and Asphalt**
- **Effect of Limestone Aggregates – No Reaction**
- **Effect of Lime- PPA Reacts with Lime?**





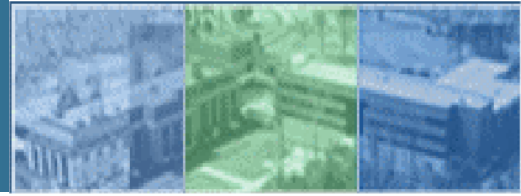
Effect on Stripping:

Hamburg 20,000
Passes 50°C



Criterion is “Does PPA increase or decrease rutting?”

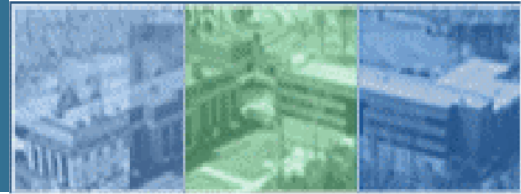




Hamburg Tests

- Effect of:
 - Phosphoric Acid Alone
 - Phosphoric Acid with
 - Lime
 - Liquid Anti-strips

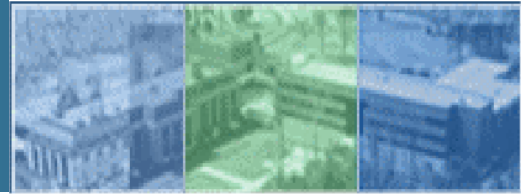




Materials Used

- Asphalt - CITGO and BP Whiting
- Aggregates:
 - “Stripping” Sandstone Maryland
 - Limestone Maryland
 - Granite Georgia
 - Diabase Virginia

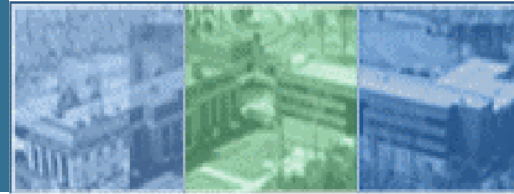




Effect of Phosphoric Acid Alone

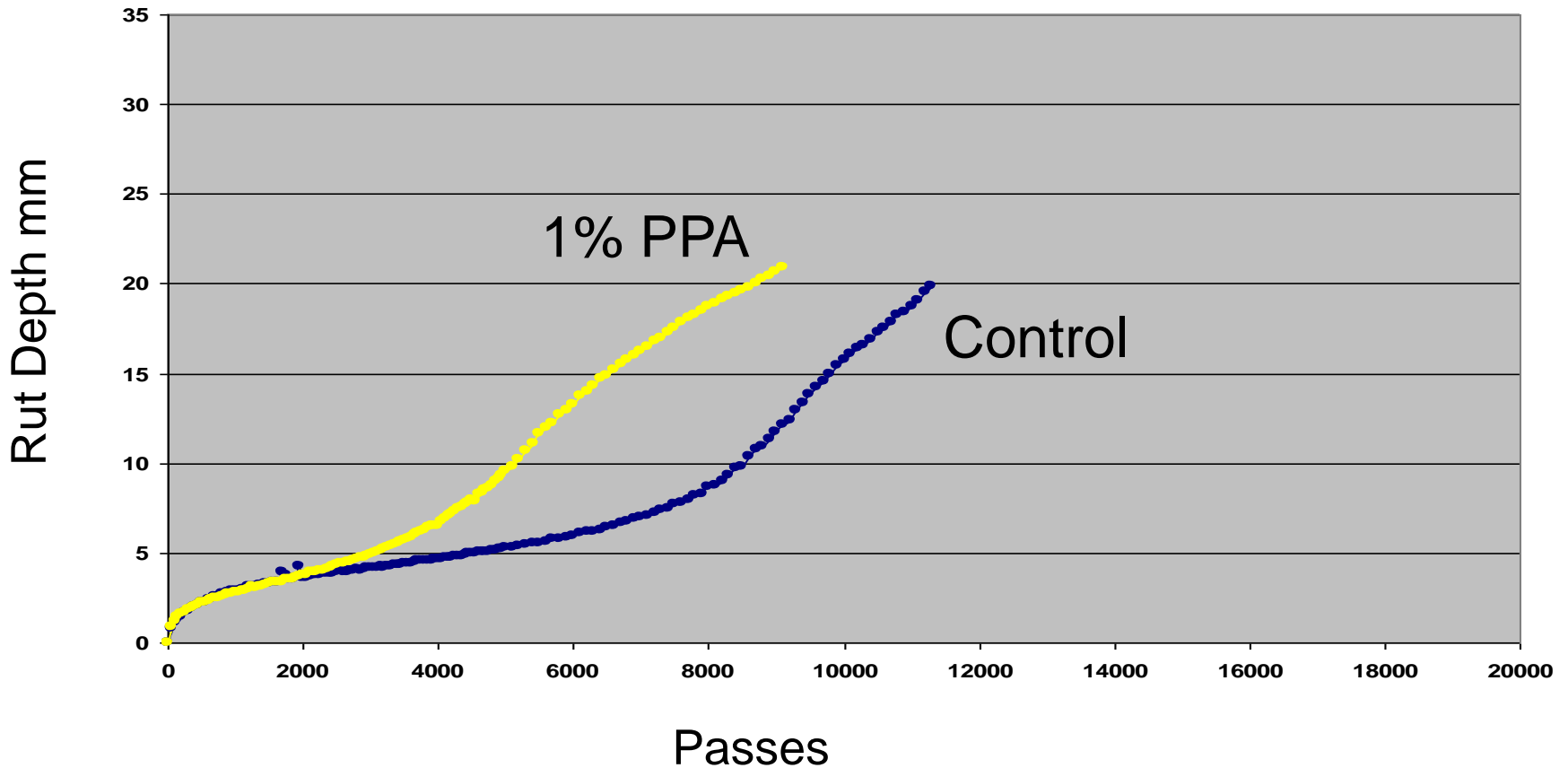
- Control samples contain no antistrip and no phosphoric acid
- Test sample is modified with phosphoric acid and contains no antistrip

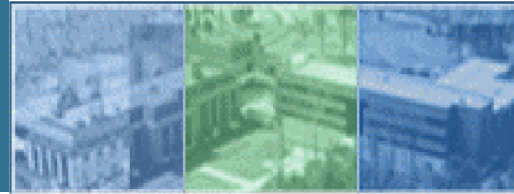




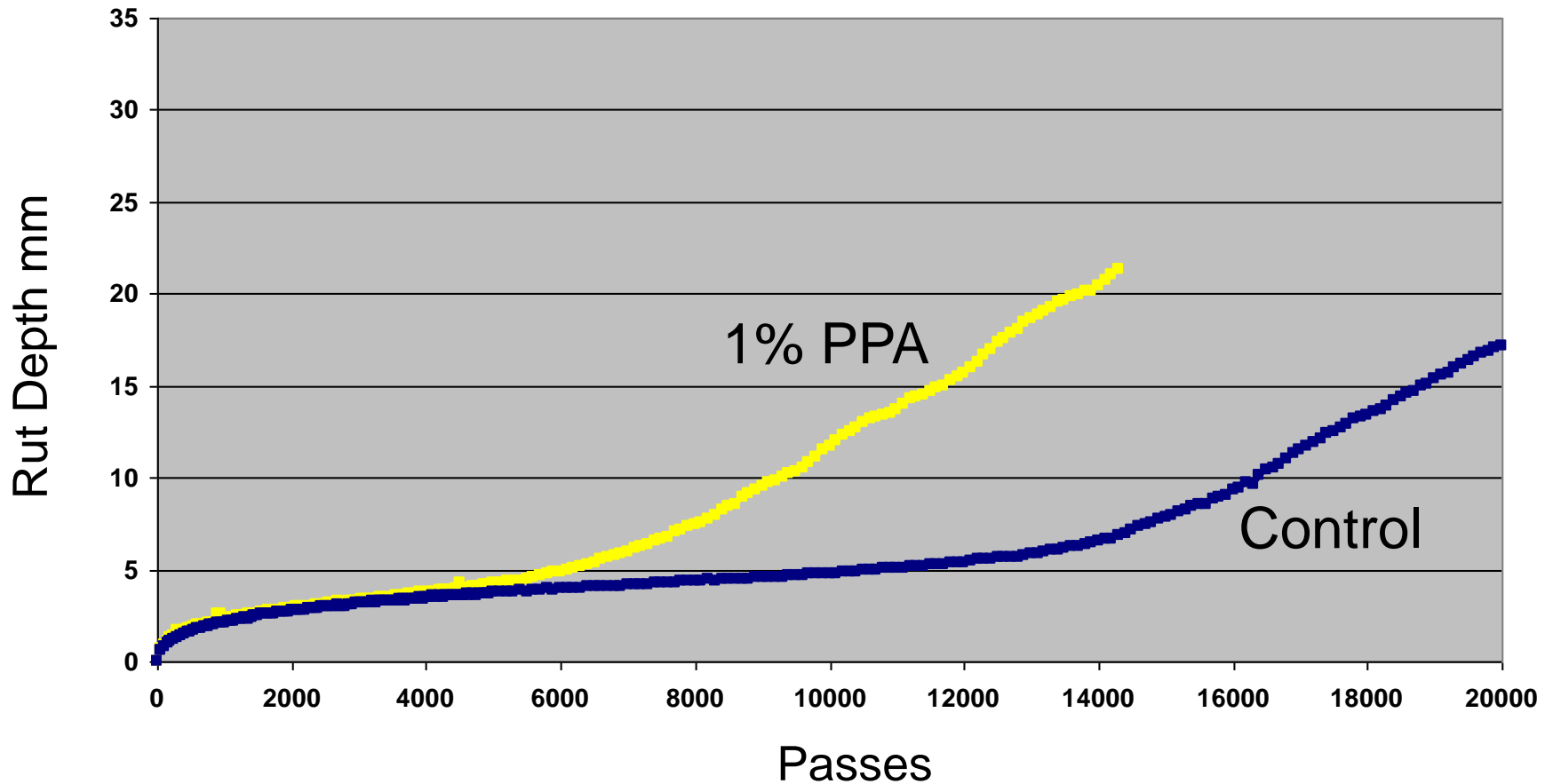
CITGO Asphalt with Limestone

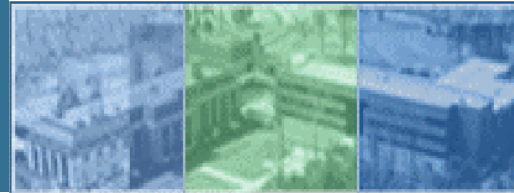
Average of Two Cores



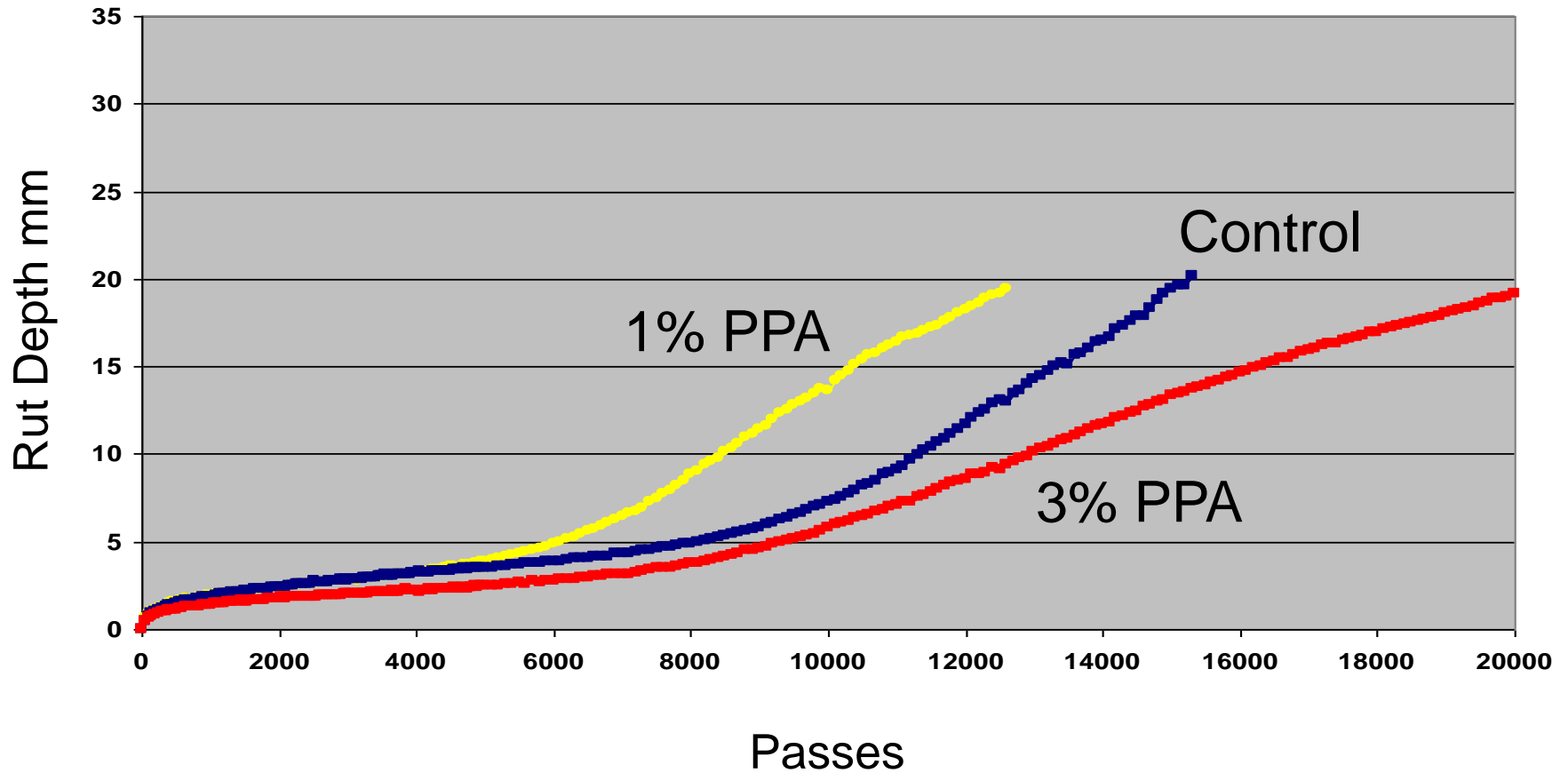


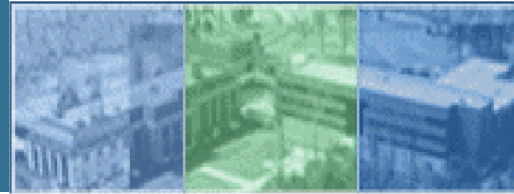
CITGO Asphalt with GA Granite





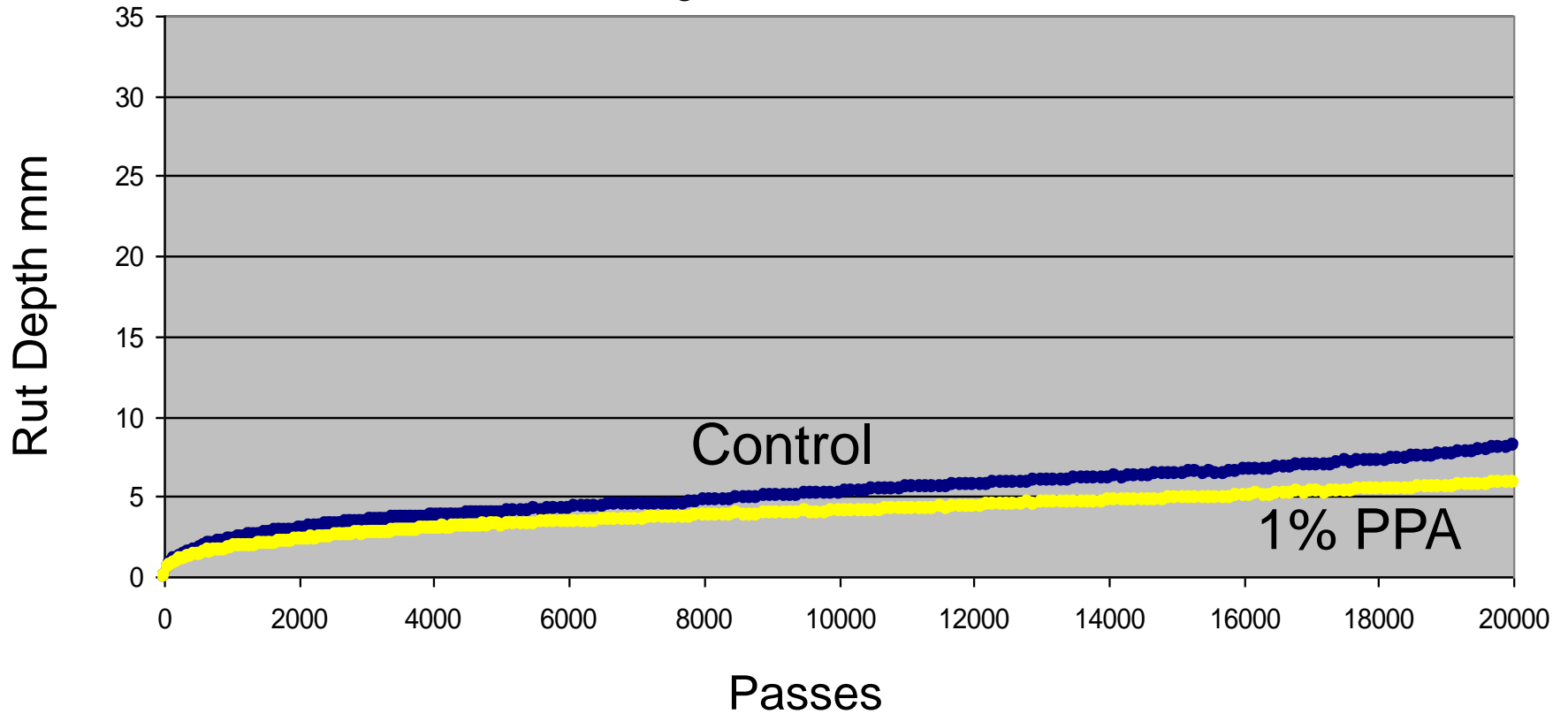
CITGO Asphalt with Sandstone

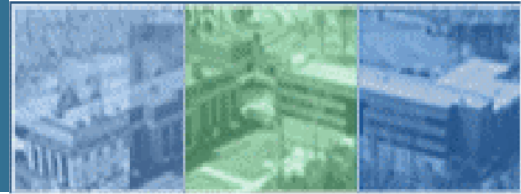




BP Whiting Asphalt with Diabase

Average of Two Cores

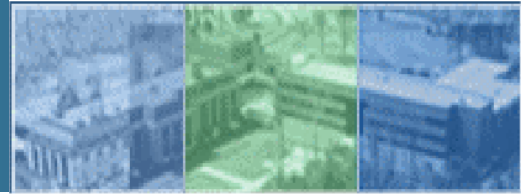




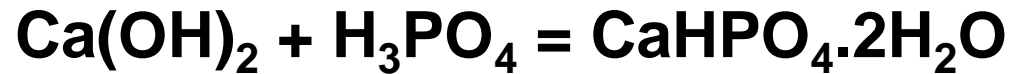
Phosphoric Acid Alone

- The addition of 1% PPA to the binder may affect the resistance of the mix to stripping as measured by the Hamburg Wheel Tracking Test





The effect of Lime Treatment on Aggregates



74 lbs

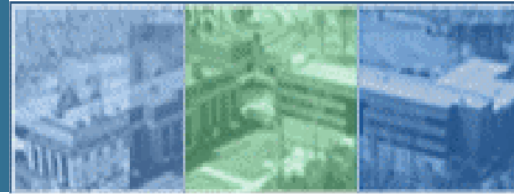
98 lbs

172 lbs

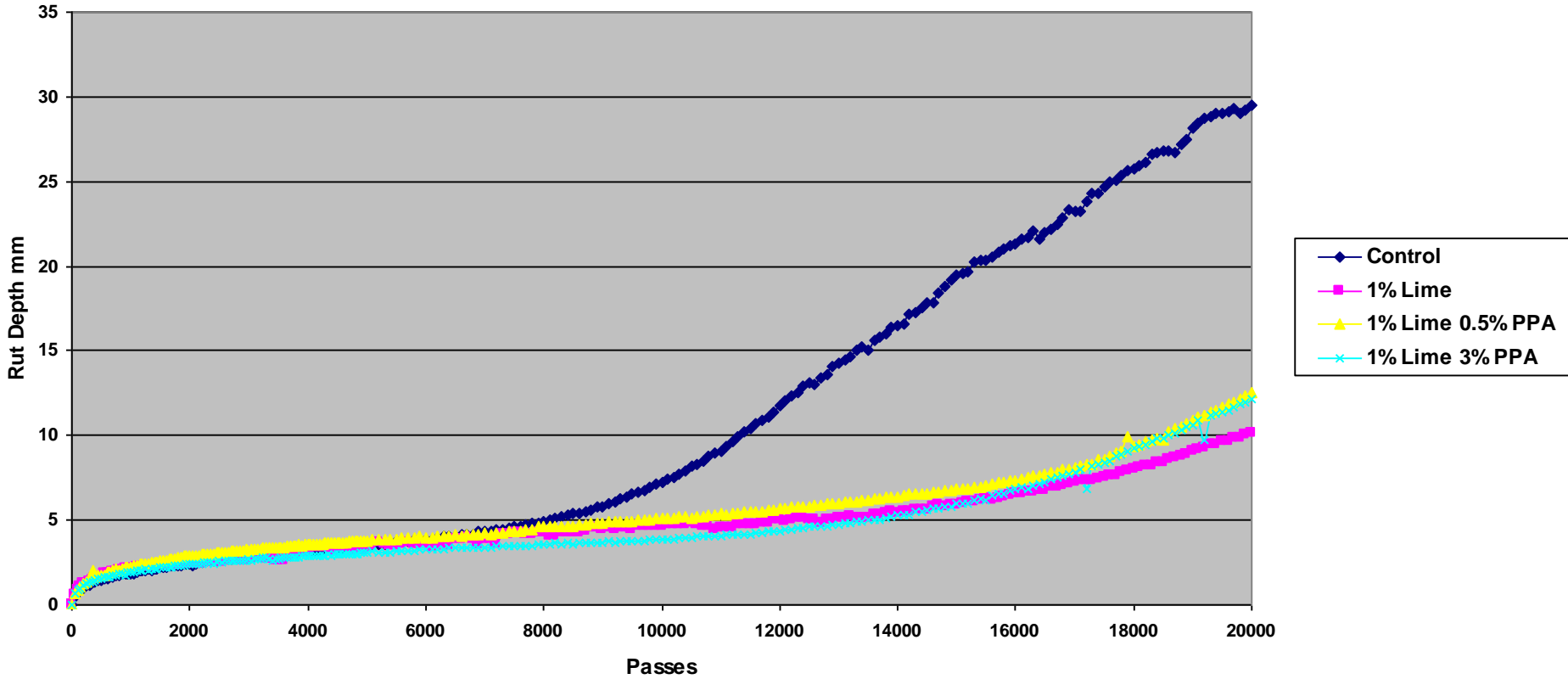
**If the mix contains 1% Lime and 1%
Phosphoric Acid there is a Large Excess of
Lime (25X)**



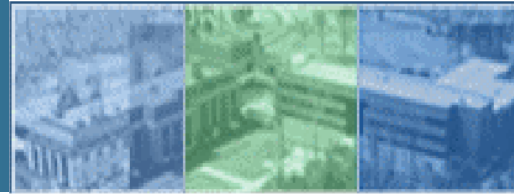
TURNER-FAIRBANK HIGHWAY RESEARCH CENTER



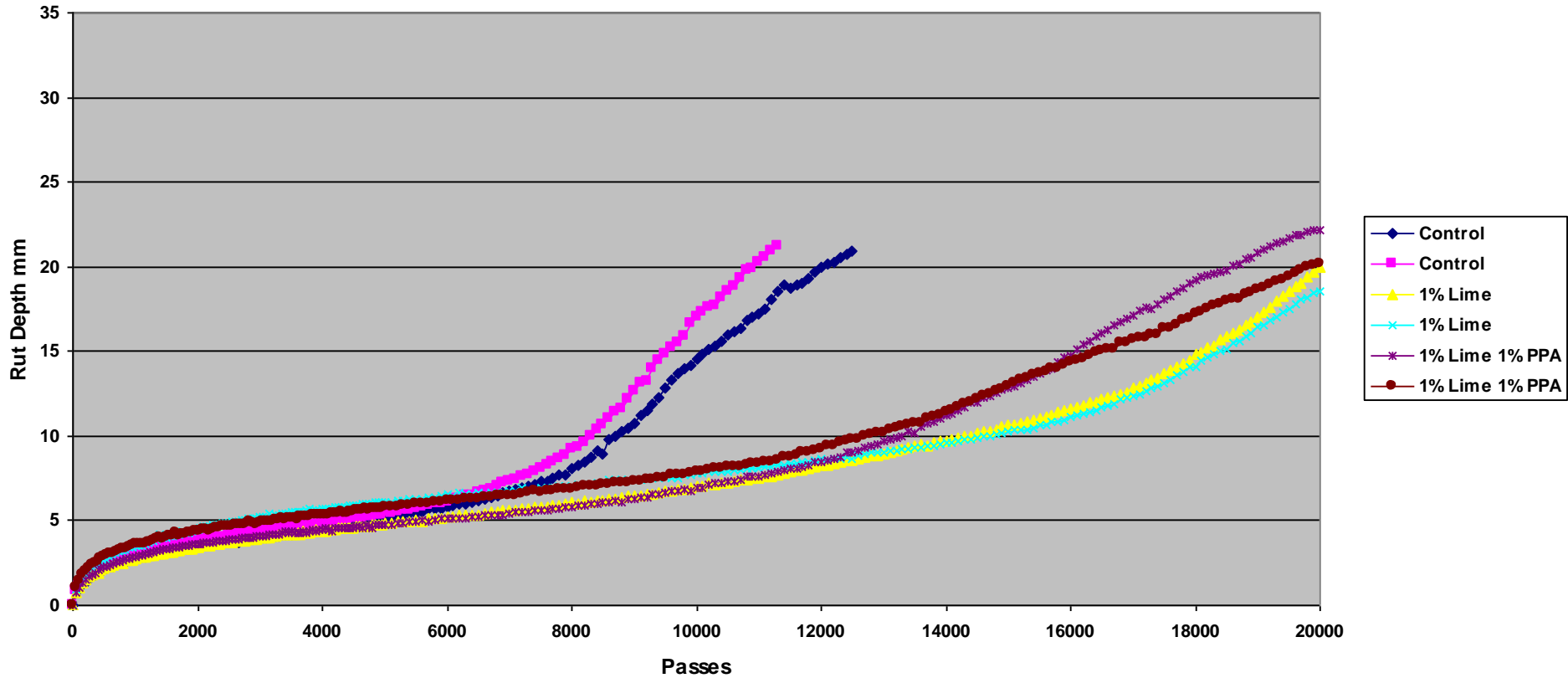
Hamburg 50degC Citgo Asphalt Lime Treated Sandstone Aggregate

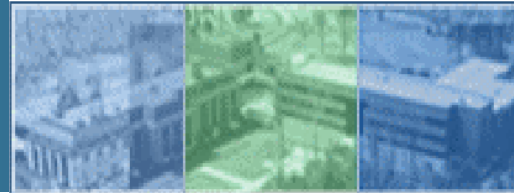


TURNER-FAIRBANK HIGHWAY RESEARCH CENTER

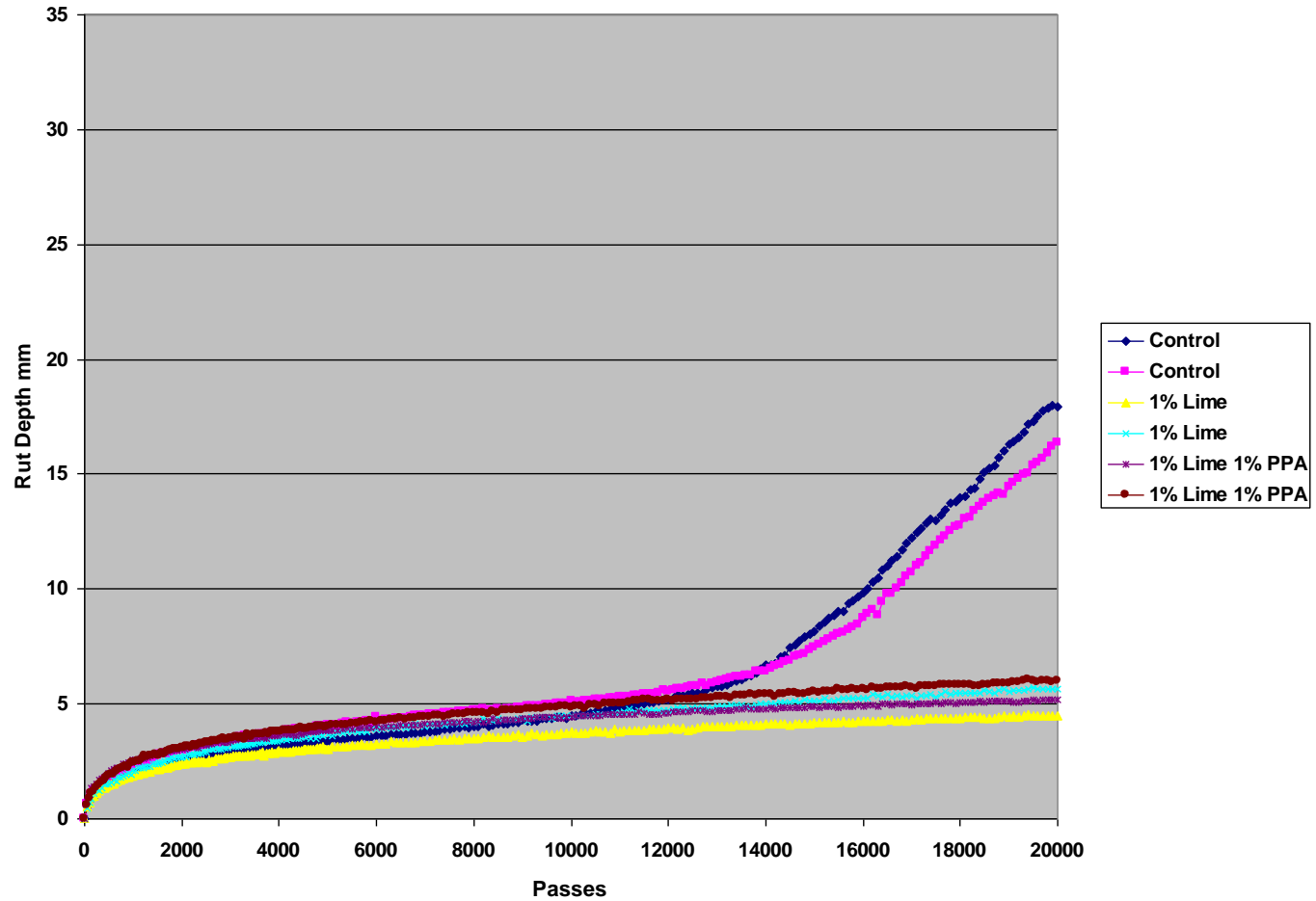


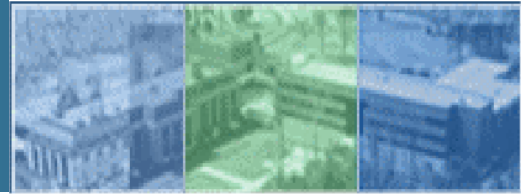
Hamburg 50degC Citgo Asphalt Lime Treated Limestone Aggregate





Hamburg 50degC Citgo Asphalt GA Granite Aggregate

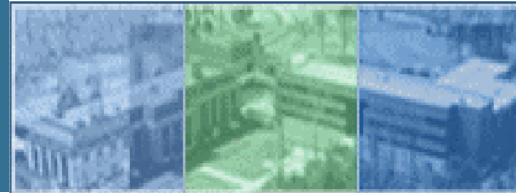




Lime Treated Aggregate

- Lime improved the Hamburg Results for all three aggregates
- This improvement was unaffected by PPA modification

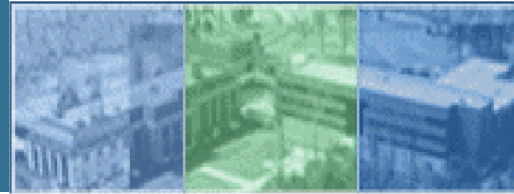




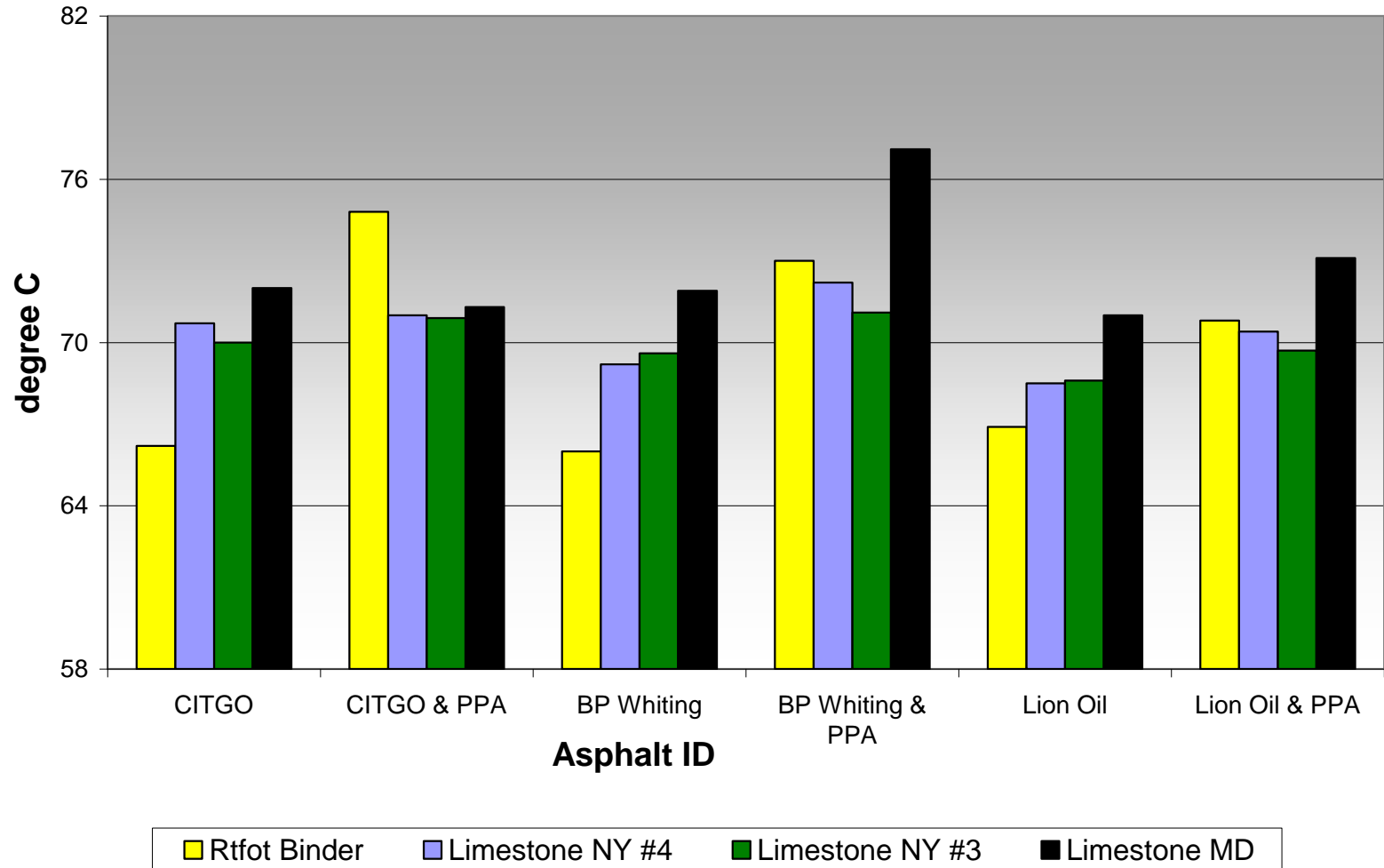
Hamburg Testing-Liquid Antistrips

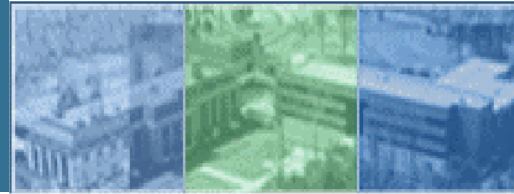
PPA %	Aggregate	Antistrip	Cycles to Failure	More or Less Rutting?
0	Granite	Innovalt-W	>20,000	
1	Granite	Innovalt-W	>20,000	Same
0	Sandstone	Innovalt-W	>20,000	
1	Sandstone	Innovalt-W	12,600	More
0	Limestone	Innovalt-W	13,000	
1	Limestone	Innovalt-W	14,700	Less
0	Granite	LOF 65-00	>20,000	
1	Granite	LOF 65-00	>20,000	Same
0	Sandstone	LOF 65-00	19,000	
1	Sandstone	LOF 65-00	>20,000	Less
0	Limestone	LOF 65-00	14,200	
1	Limestone	LOF 65-00	9,300	More
0	Granite	LA-2	>20,000	
1	Granite	LA-2	>20,000	Same
0	Sandstone	LA-2	15,500	
1	Sandstone	LA-2	11,700	More
0	Limestone	LA-2	13,700	
1	Limestone	LA-2	8,100	More



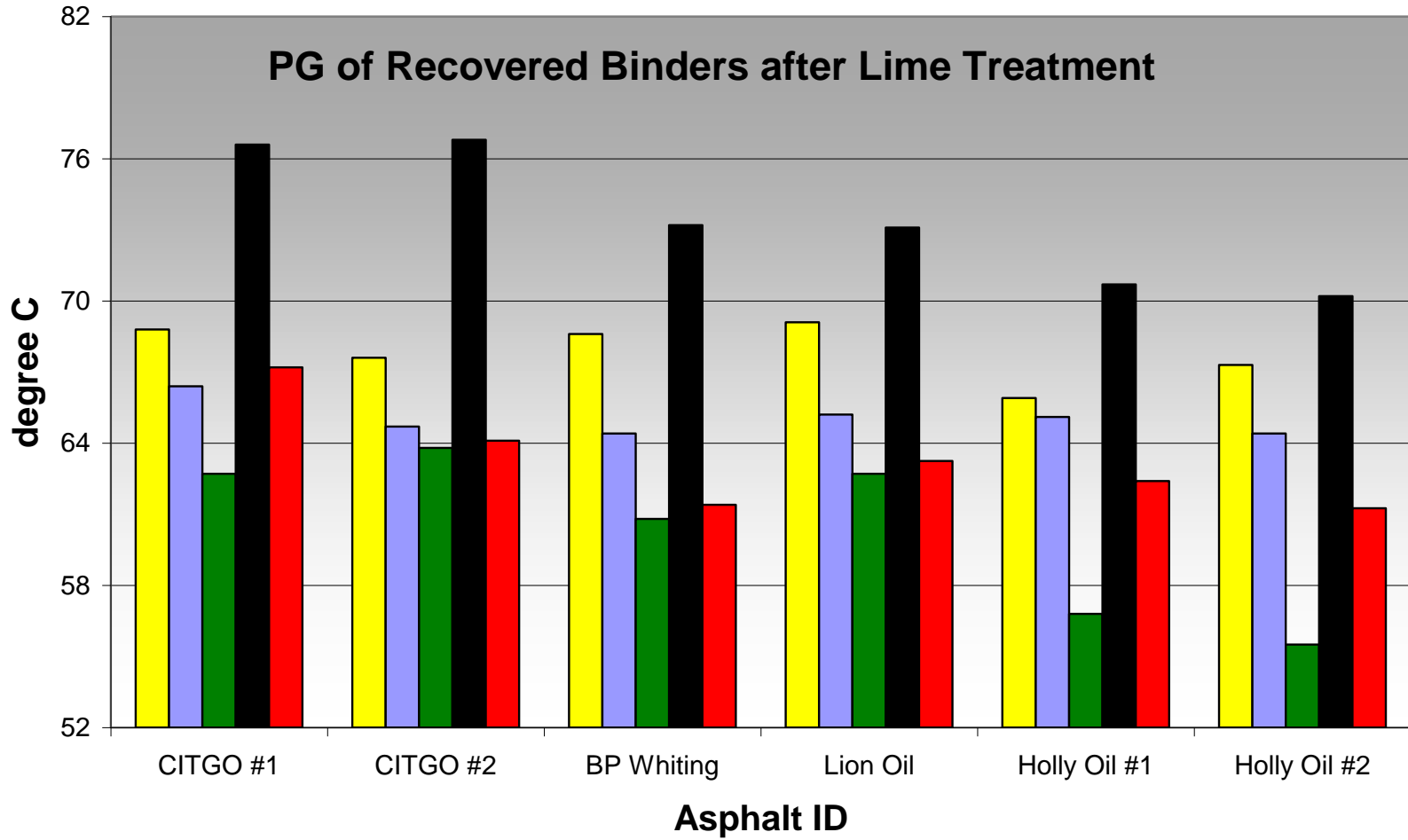


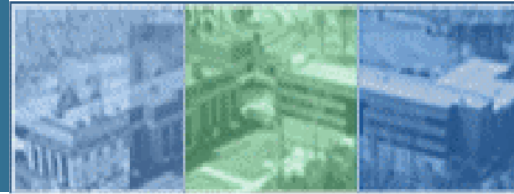
PG of Recovered Binders from Limestone HMA



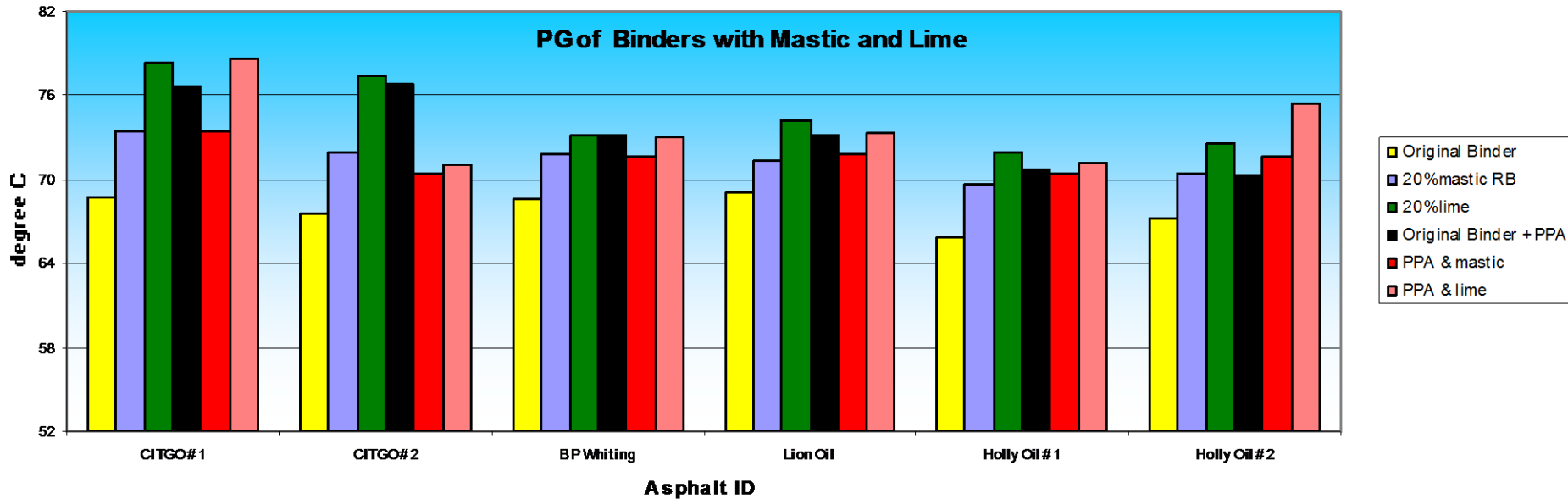


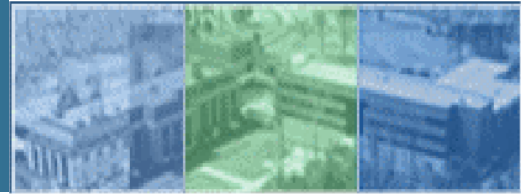
Lime Treatment- Dust Removed





Lime and Dust Treatment Solids not Removed

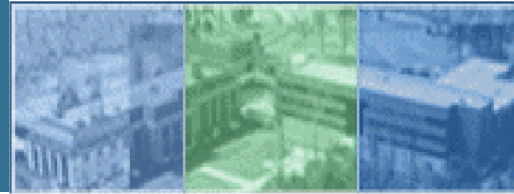




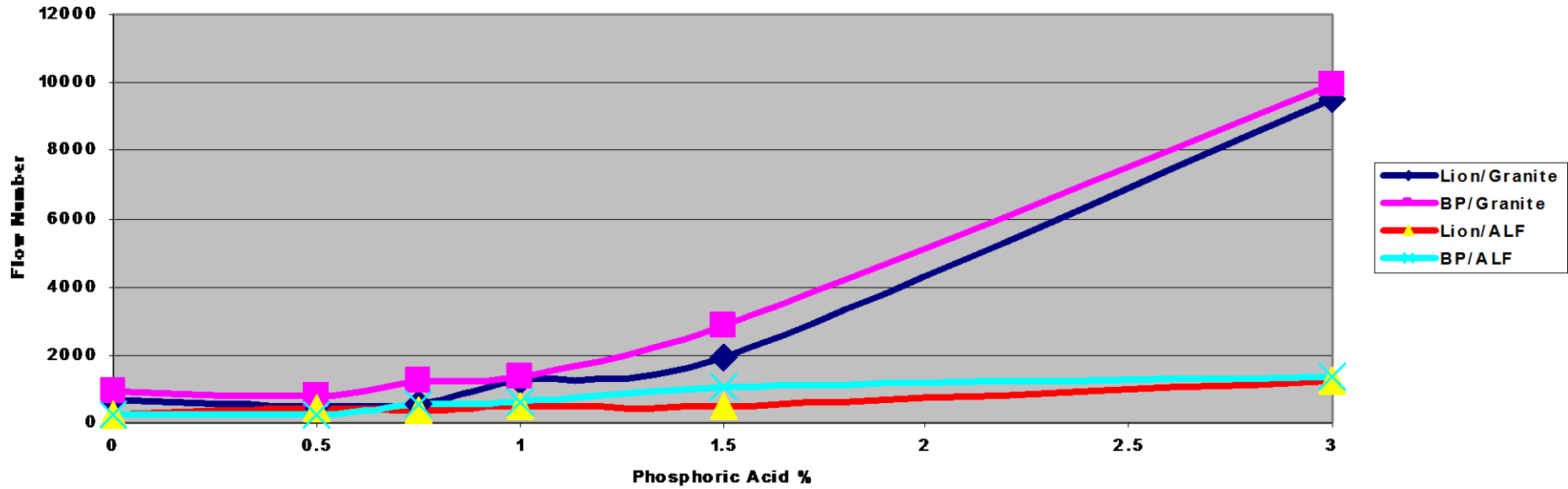
Change in PG DegC

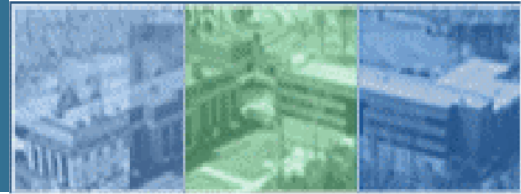
	Holly	Holly	Citgo	Citgo	Lion	BP
20% Dust	3.8	3.2	4.7	4.3	2.3	3.2
20% Lime	6.1	5.3	9.6	9.8	5.1	4.6
0.75% PPA	4.8	2.9	9.8	9.2	4	4.6
PPA + Dust	4.5	4.4	4.7	2.8	2.7	3.1
PPA + Lime	4.5	8.1	9.8	3.4	4.2	4.4





SPT of Gyratory Specimens After Water Soaking for 245 Days



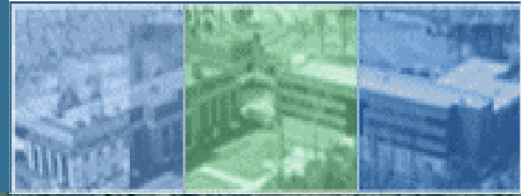


Conclusions

- Phosphoric Acid may affect the rutting and stripping of mixes as determined by the Hamburg Wheel Tracking Test
- Mixes should be thoroughly tested using the asphalt/aggregate/antistrip combination being used.
- Phosphoric acid in asphalt does not react with limestone aggregates
- Phosphoric Acid in asphalt does react with lime.

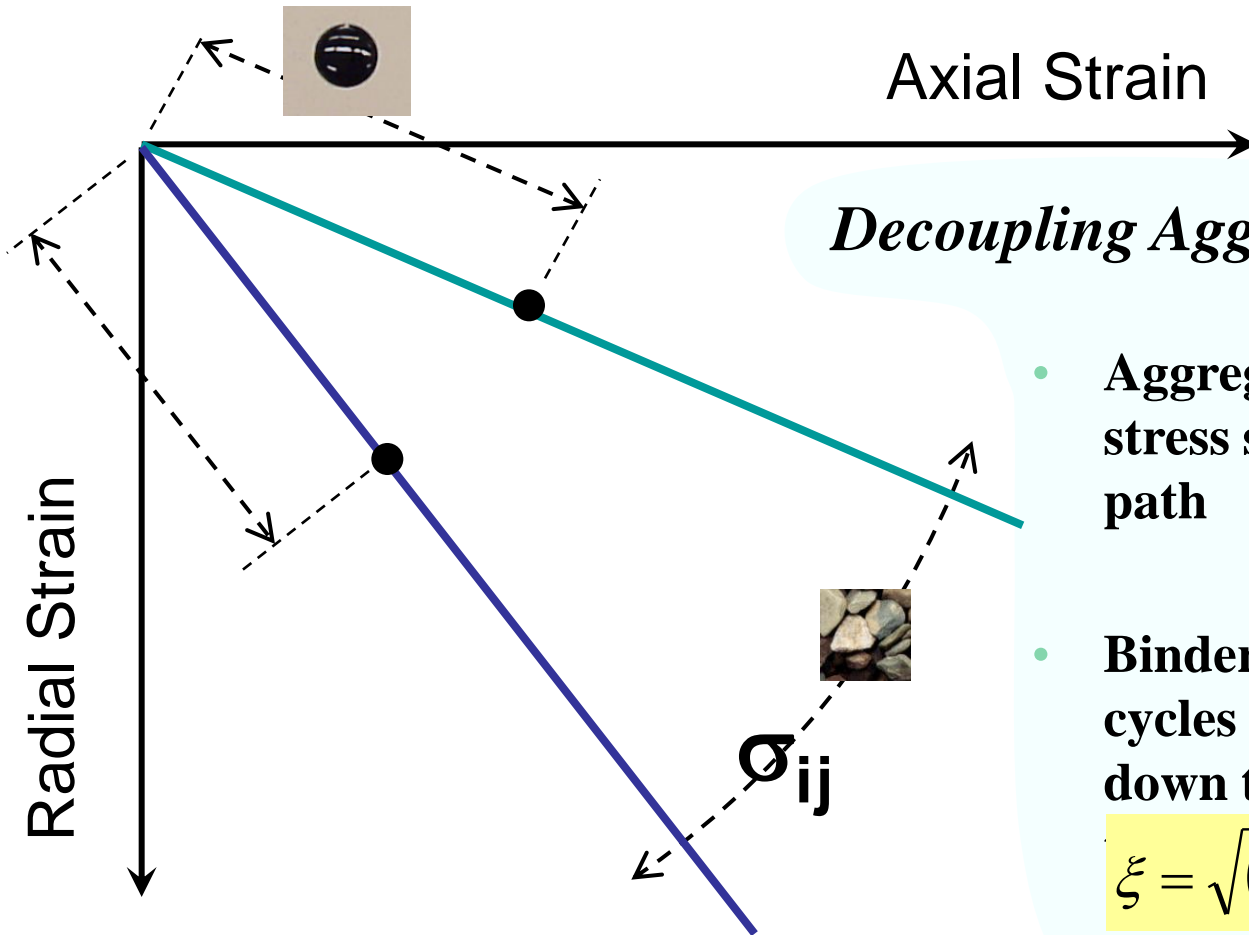
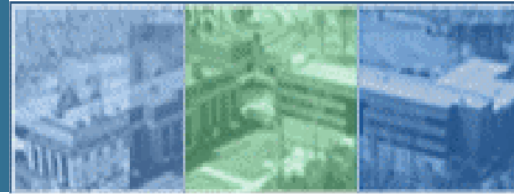


TURNER-FAIRBANK HIGHWAY RESEARCH CENTER



Thank You



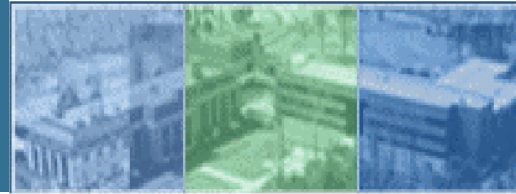


Decoupling Aggregate and Binder

- Aggregate structure and stress state determine strain path
- Binder type and number of cycles determine how far down the strain path loading

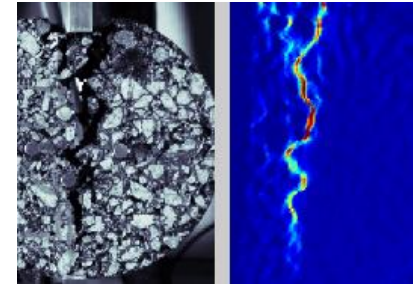
$$\xi = \sqrt{(\varepsilon_{Axial})^2 + 2(\varepsilon_{Radial})^2}$$





Motivation & Objective

...think of Cracking as localized / planar



...think of Rutting as a multi-dimensional distress and asphalt concrete as a partially saturated soil; asphalt binder being the pore fluid

