Update on Research into the Phosphoric Acid Modification of Asphalt

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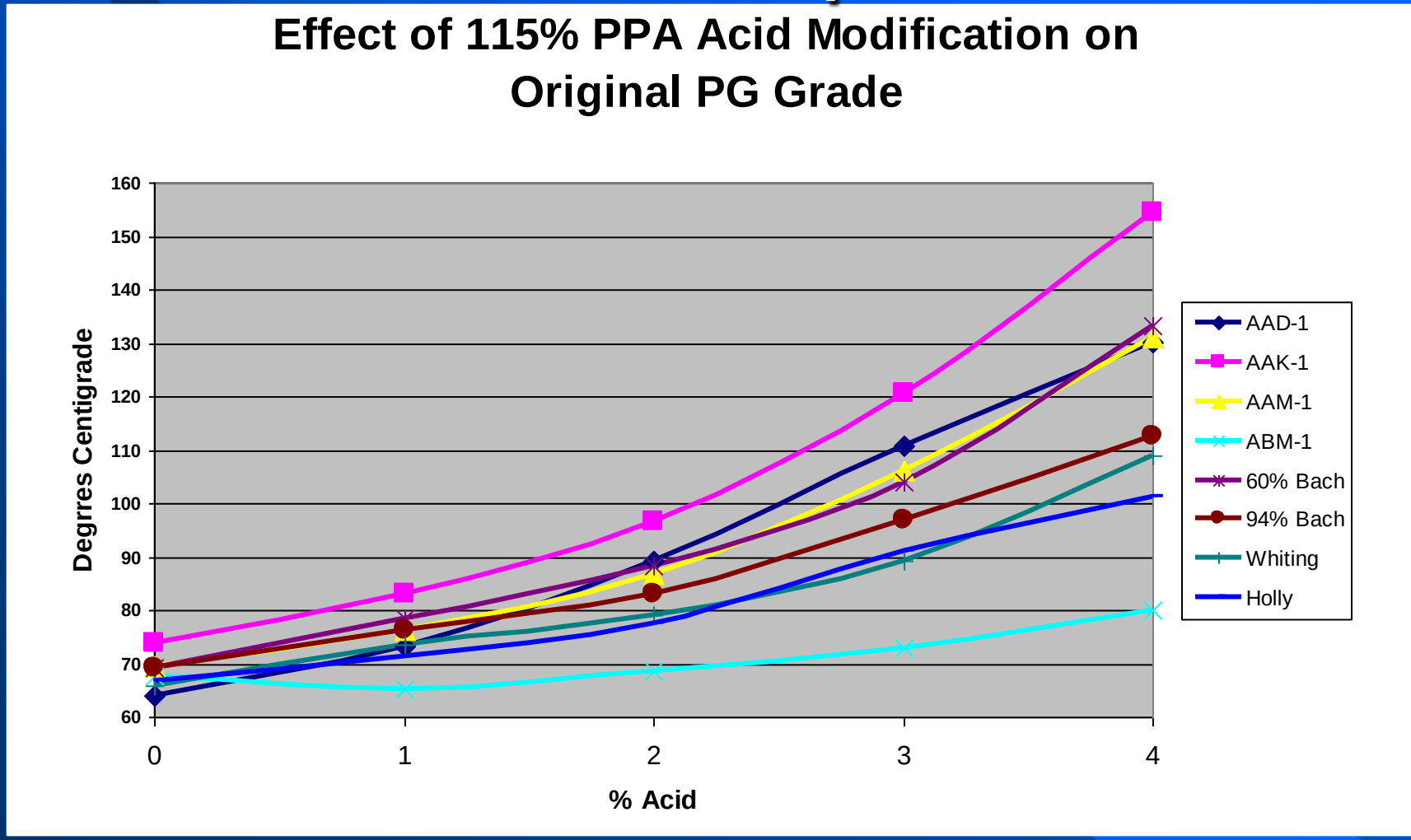
Effect of Acid Grade and Asphalt Source

- All acid grades give similar stiffness increase
- Grades containing water may give foaming problems
- Stiffness change is asphalt dependent

Acid has varied effect on different asphalts

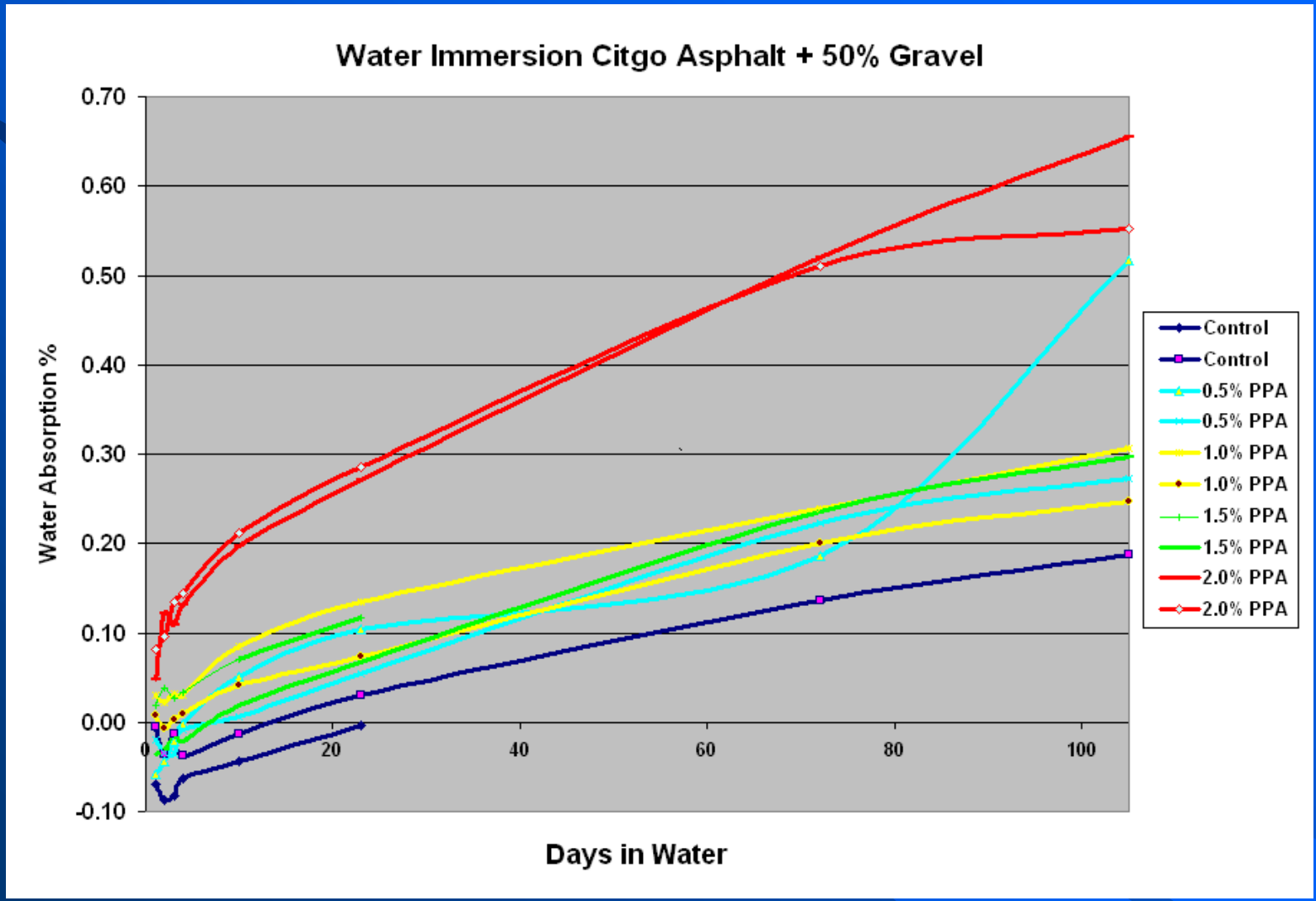


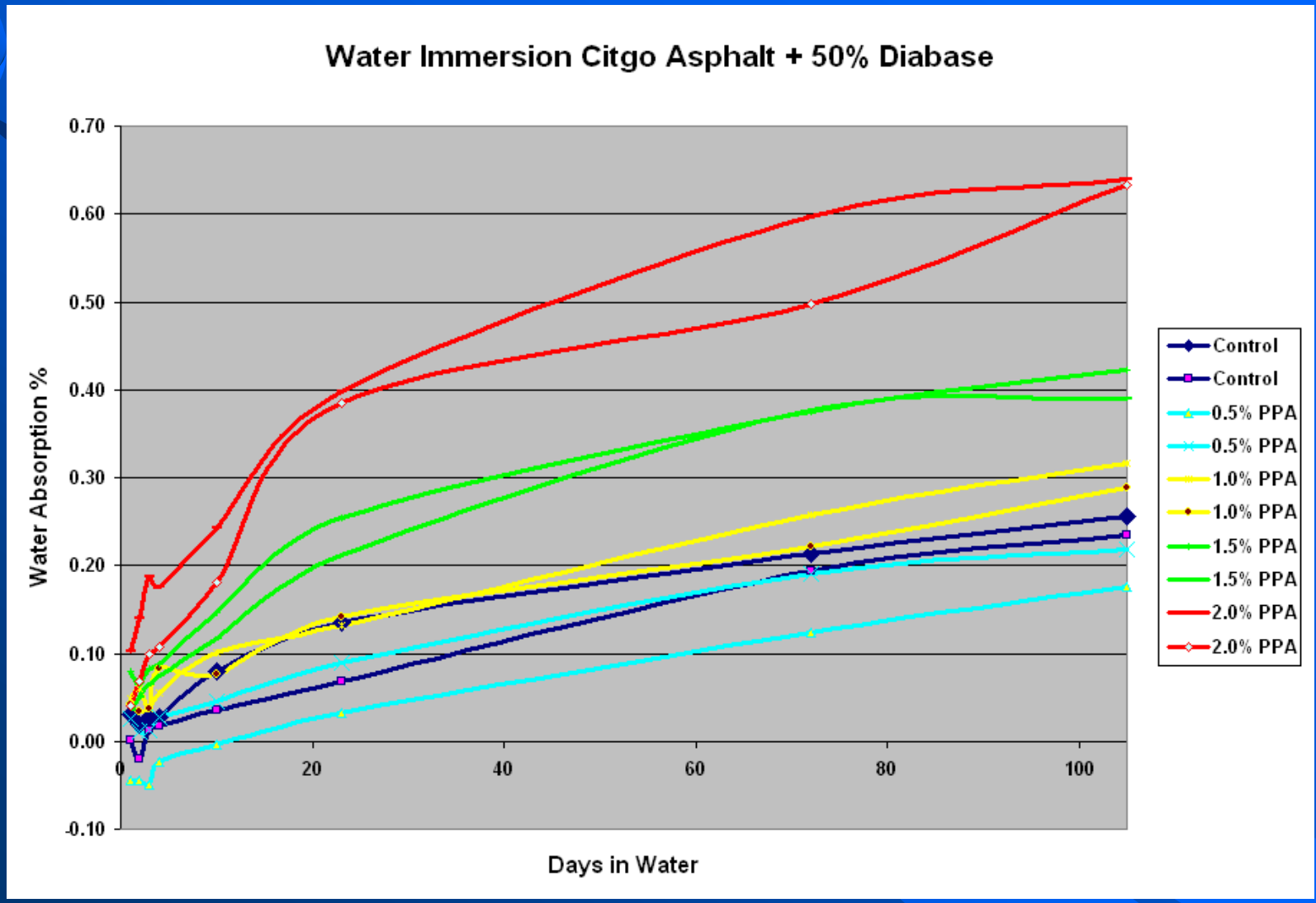
Moisture Sensitivity

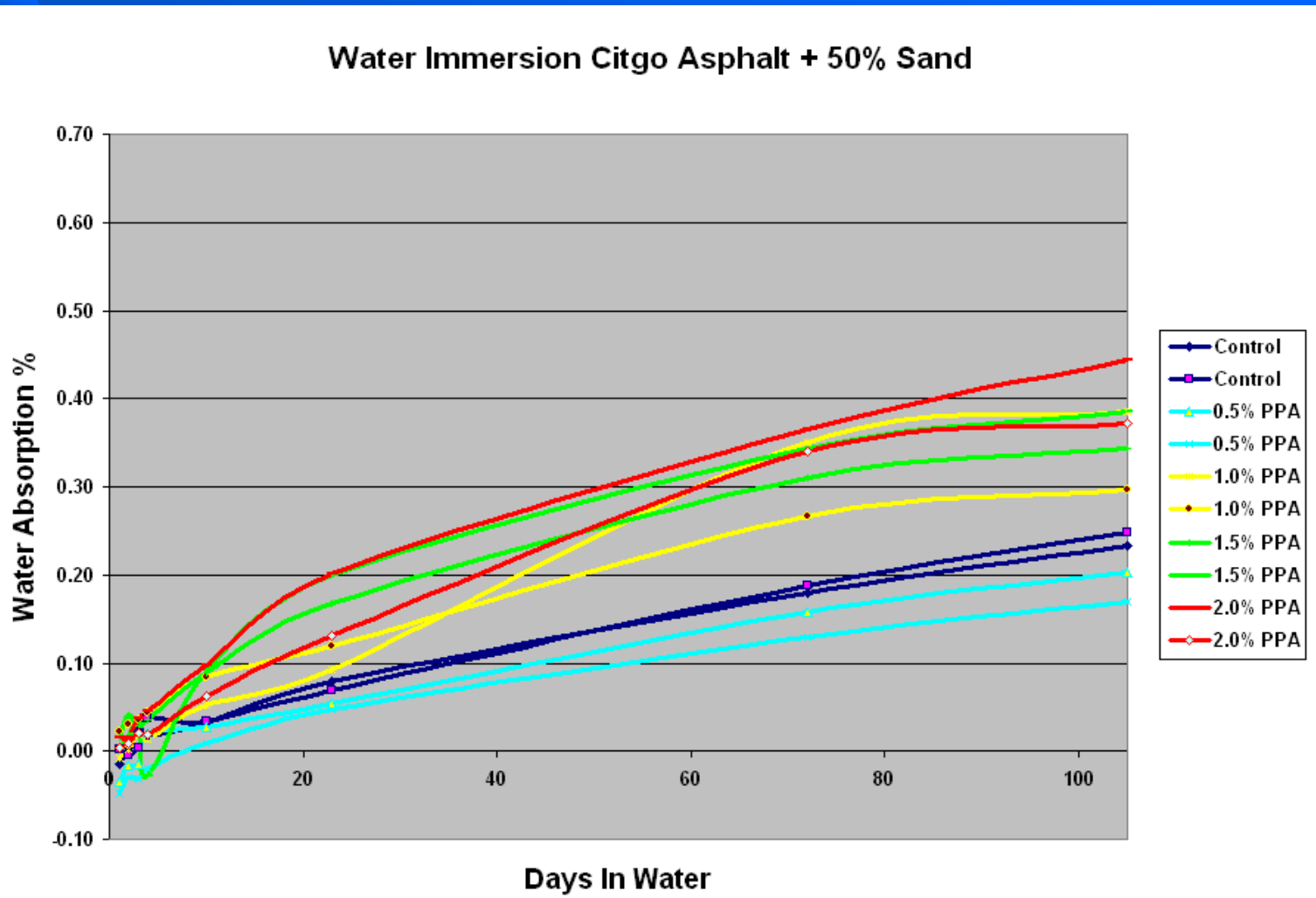
- Does adding a hydrophilic material like phosphoric acid impart moisture sensitivity to the binder?

Moisture Sensitivity

- BBR Beams and DT samples of neat binder and 50% mastics were soaked in a 45ºF water bath
- Beams were dried with a paper towel and weighed
- For this Asphalt (Citgo) water absorption increases with increasing PPA particularly at levels greater than 1-1.5%


Water Immersion Citgo Asphalt + 50% Gravel
Water Absorption %
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
20
40
60
80
100
Days in Water
Control
Control
0.5% PPA
0.5% PPA
1.0% PPA
1.0% PPA
1.5% PPA
1.5% PPA
2.0% PPA
2.0% PPA


Water Immersion Citgo Asphalt + 50% Diabase
Water Absorption %
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
20
40
60
80
100
Days in Water
Control
Control
0.5% PPA
0.5% PPA
1.0% PPA
1.0% PPA
1.5% PPA
1.5% PPA
2.0% PPA
2.0% PPA

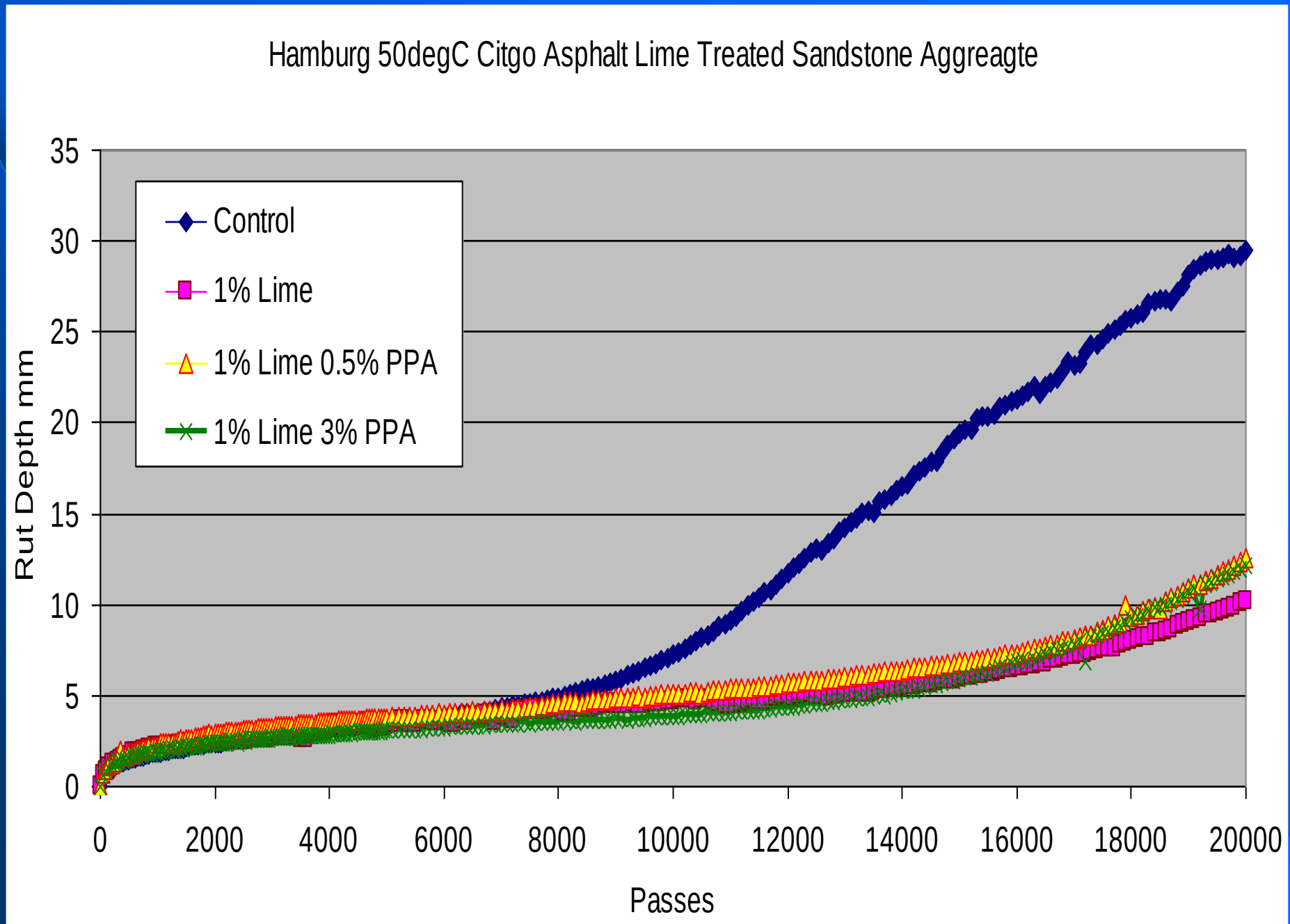

Water Immersion Citgo Asphalt + 50% Sand
Water Absorption %
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
20
40
60
80
100
Days In Water
Control
Control
0.5% PPA
0.5% PPA
1.0% PPA
1.0% PPA
1.5% PPA
1.5% PPA
2.0% PPA
2.0% PPA

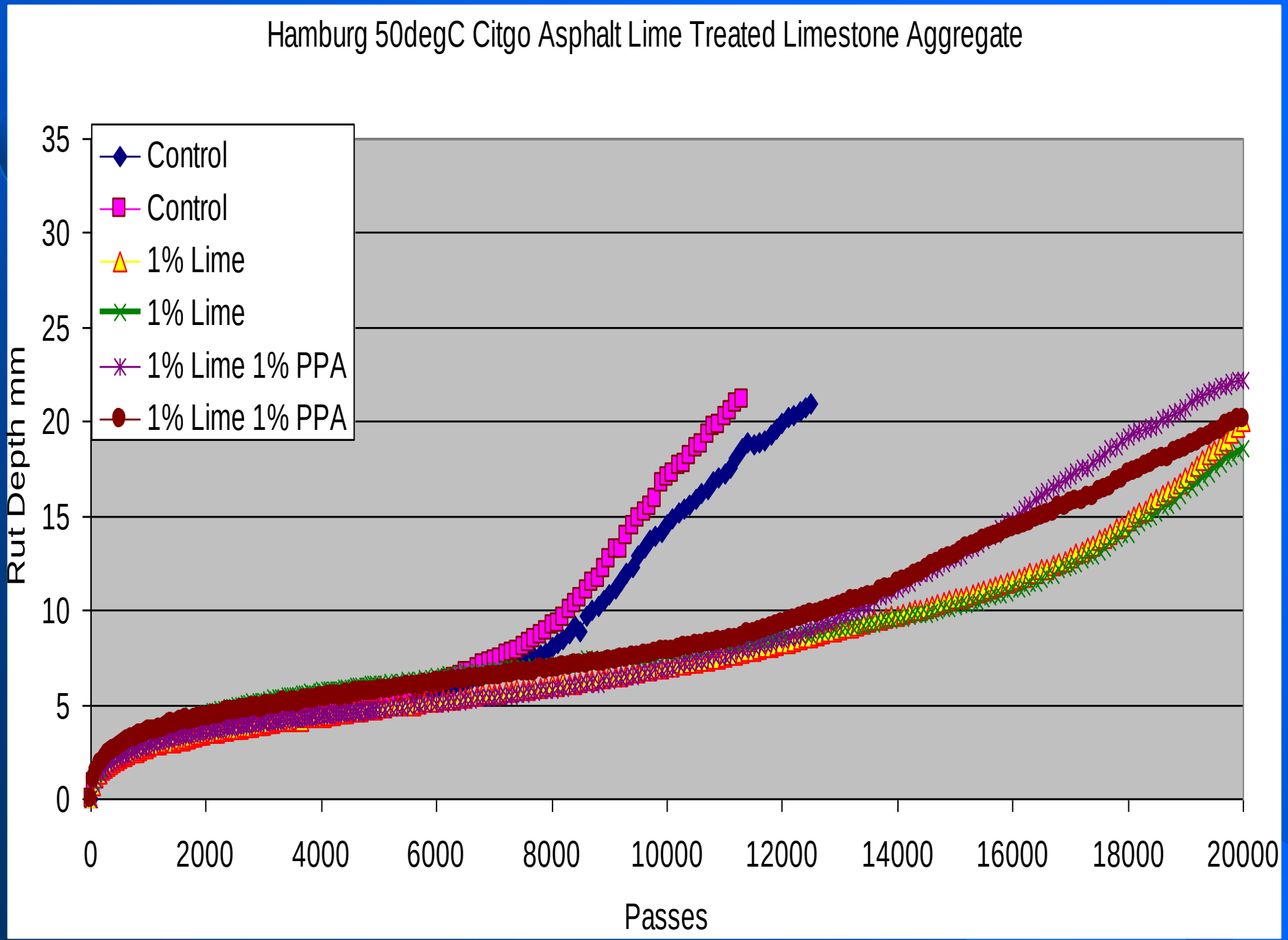
Hamburg Testing Rationale

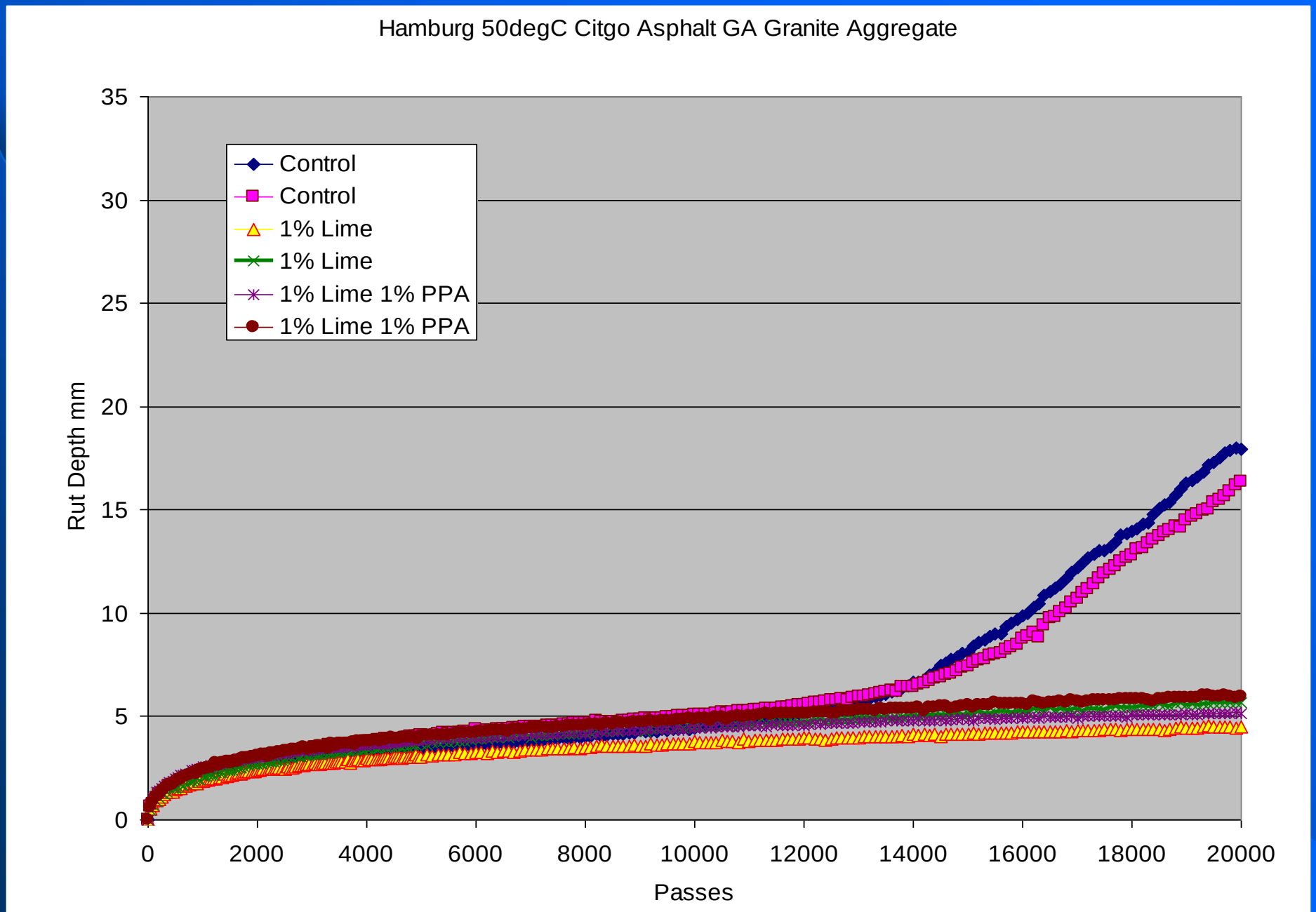
- There is no perfect test to measure stripping
- We chose Hamburg at 50^{o}C
- The tests are not meant to be exhaustive
- Criterion is “Does PPA make it better or worse”
- Tests are done in duplicate
- Both results are shown on the charts

Materials Used

- Asphalt from Citgo
- Stripping Sandstone Aggregate from MD (Banned by MDDOT)
- Limestone Aggregate from MD
- Granite from GA
- Amine Antistrip from Arr-Mazz- LA-2, LOF65-00
- Non Amine from Innophos – Innovalt-W (a phosphate ester)
- Lime from Chemical Lime Company

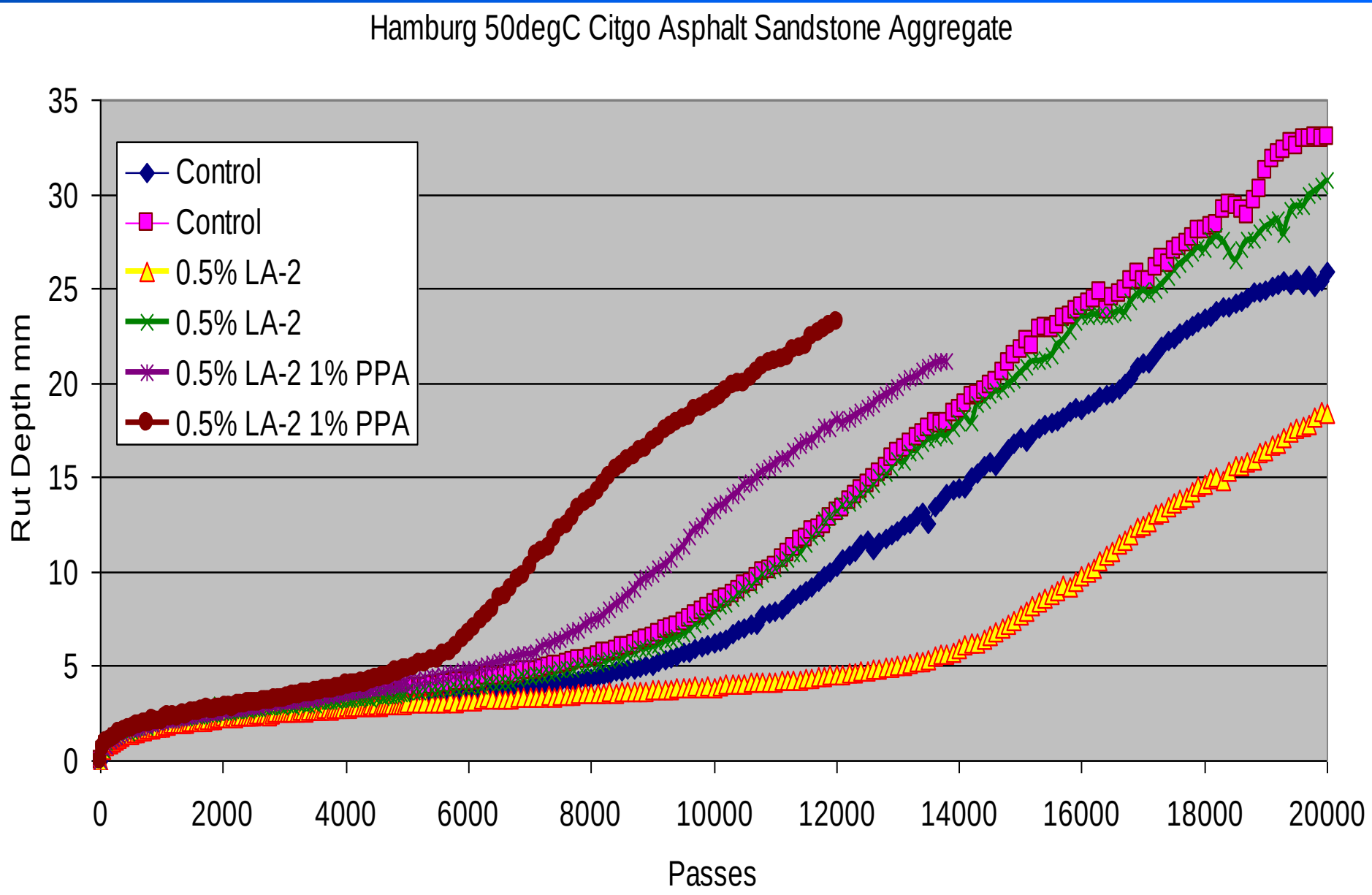

Hamburg 50degC Citgo Asphalt Lime Treated Sandstone Aggreagte
Rut Depth mm
35
30
25
20
15
10
5
0
Control
1% Lime
1% Lime 0.5% PPA
1% Lime 3% PPA
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Passes

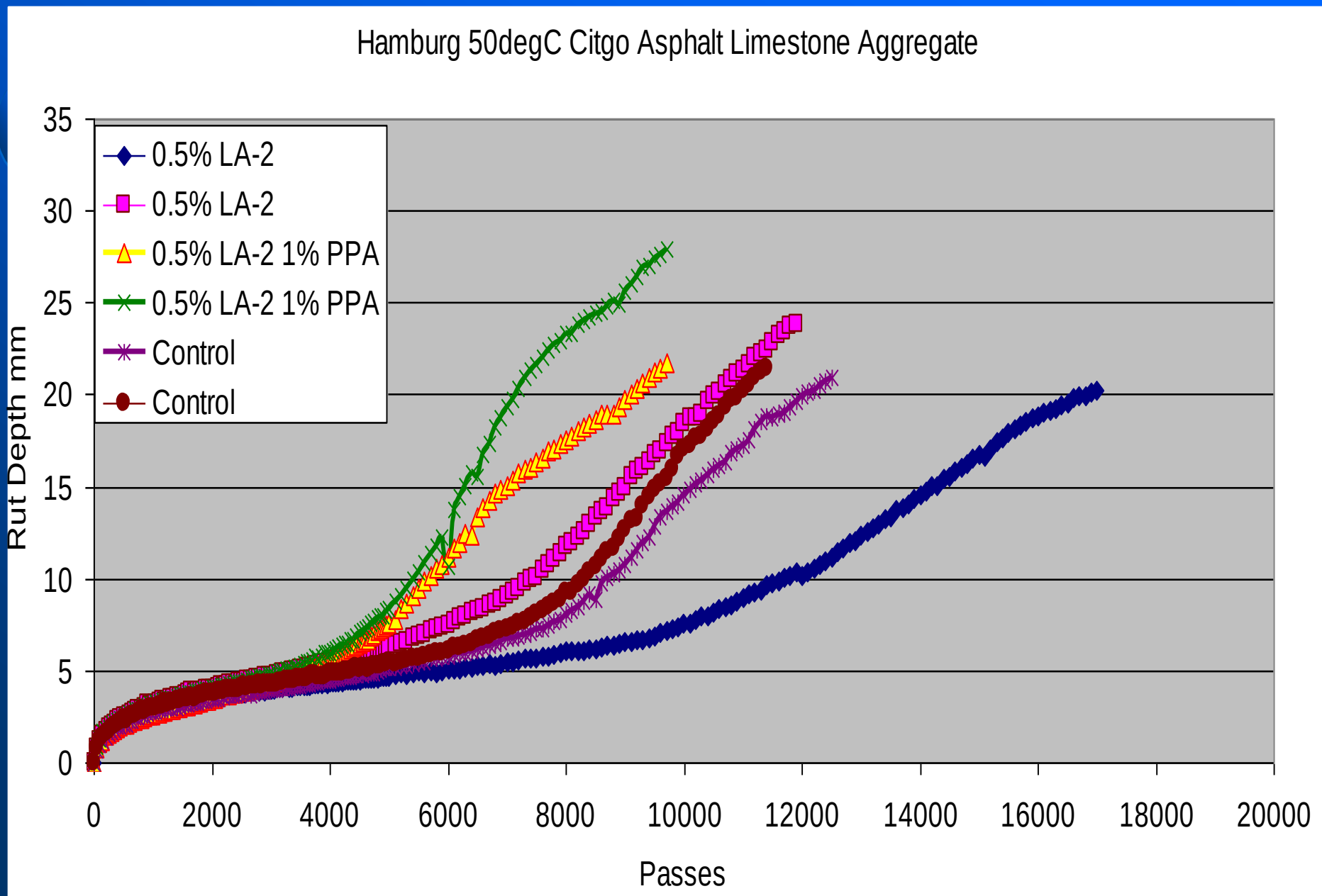

Hamburg 50degC Citgo Asphalt Lime Treated Limestone Aggregate
Control
Control
1% Lime
1% Lime
1% Lime 1% PPA
1% Lime 1% PPA
Rut Depth mm
0
5
10
15
20
25
30
35
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Passes

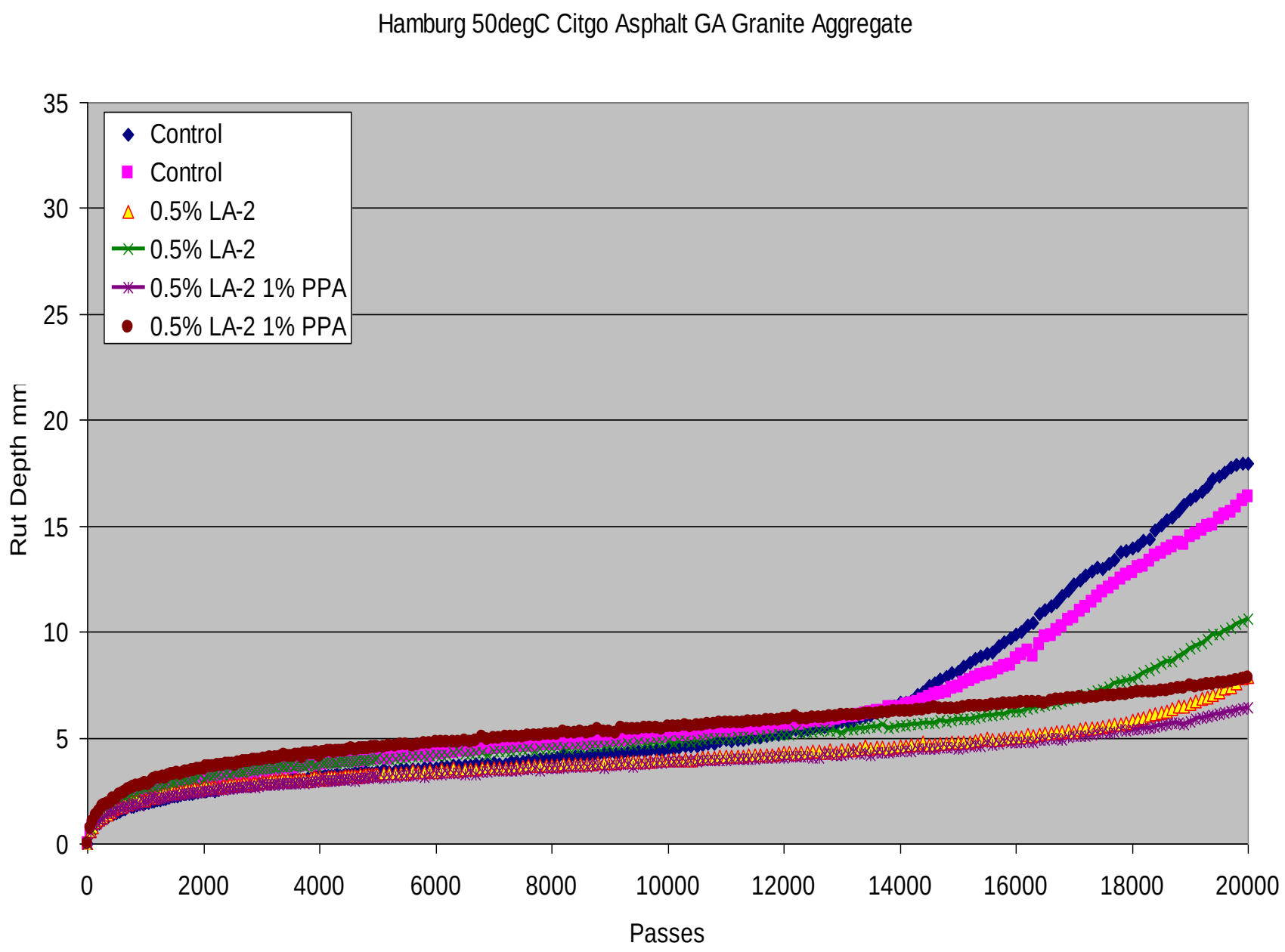

Hamburg 50degC Citgo Asphalt GA Granite Aggregate
Rut Depth mm
Passes
0
5
10
15
20
25
30
35
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Control
Control
1% Lime
1% Lime
1% Lime 1% PPA
1% Lime 1% PPA

Lime Treated Aggregate

- **Lime showed up very well in the tests**
- **Stripping was unaffected by PPA modification**


Hamburg 50degC Citgo Asphalt Sandstone Aggregate
Rut Depth mm
Passes
0
5
10
15
20
25
30
35
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Control
Control
0.5% LA-2
0.5% LA-2
0.5% LA-2 1% PPA
0.5% LA-2 1% PPA

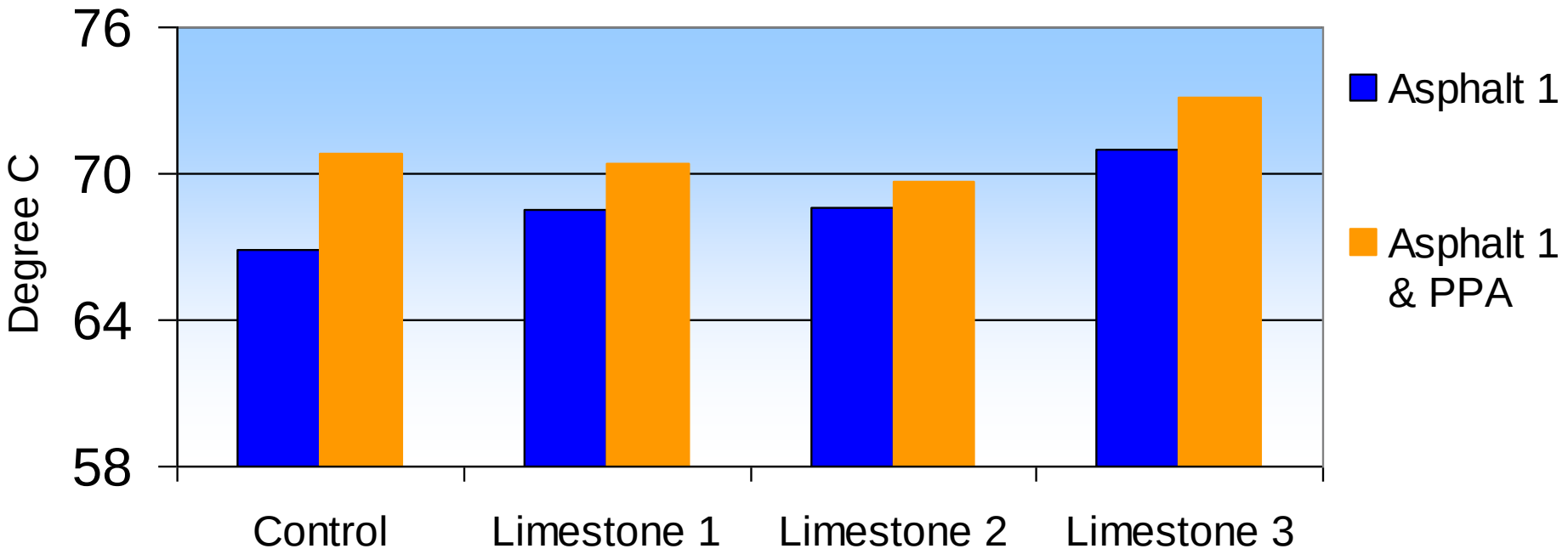

Hamburg 50degC Citgo Asphalt Limestone Aggregate
Rut Depth mm
Passes
0.5% LA-2
0.5% LA-2
0.5% LA-2 1% PPA
0.5% LA-2 1% PPA
Control
Control
0
5
10
15
20
25
30
35
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000


Hamburg 50degC Citgo Asphalt GA Granite Aggregate
Control
Control
0.5% LA-2
0.5% LA-2
0.5% LA-2 1% PPA
0.5% LA-2 1% PPA
Rut Depth mm
0
5
10
15
20
25
30
35
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Passes

Conclusions – Hamburg Testing

- Test is only an indication and was with a single asphalt
- PPA increased moisture sensitivity of the neat binders
- Action of amine and phosphate ester antistrips is aggregate specific- PPA generally increases moisture sensitivity
- With lime treated aggregates the moisture sensitivity is unaffected by PPA modification
- Users need to test each asphalt/aggregate/antistrip combination.

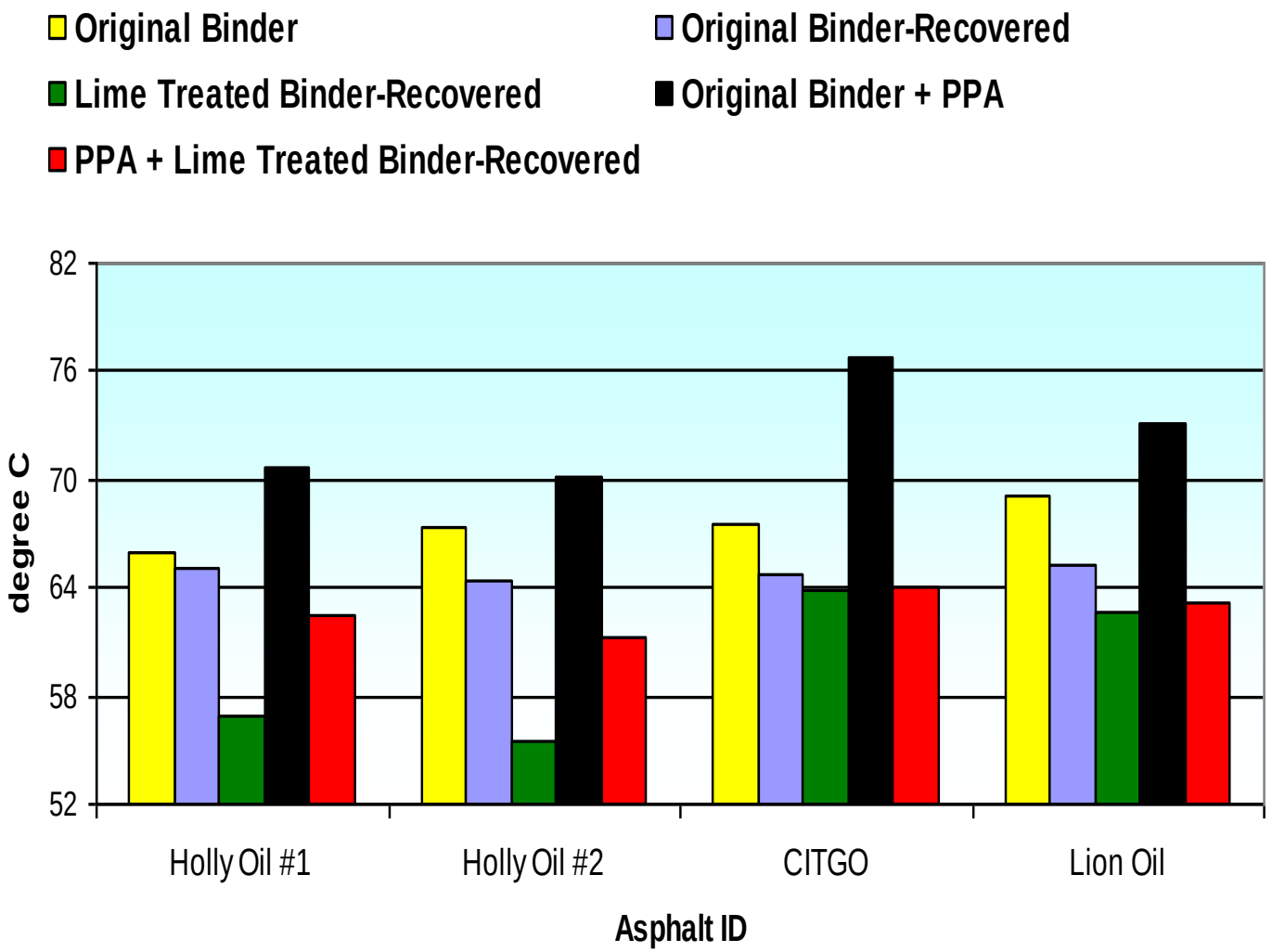
Binders mixed with limestone agg. and extracted



Effect of Limestone Aggregate on PPA modified binder

- Multiple Limestone aggregates, Dolomitic, Calcium Carbonate, did not neutralize the PPA modified binders.
- There was no loss of PG grade.

Binders mixed with hydrated lime and then extracted.



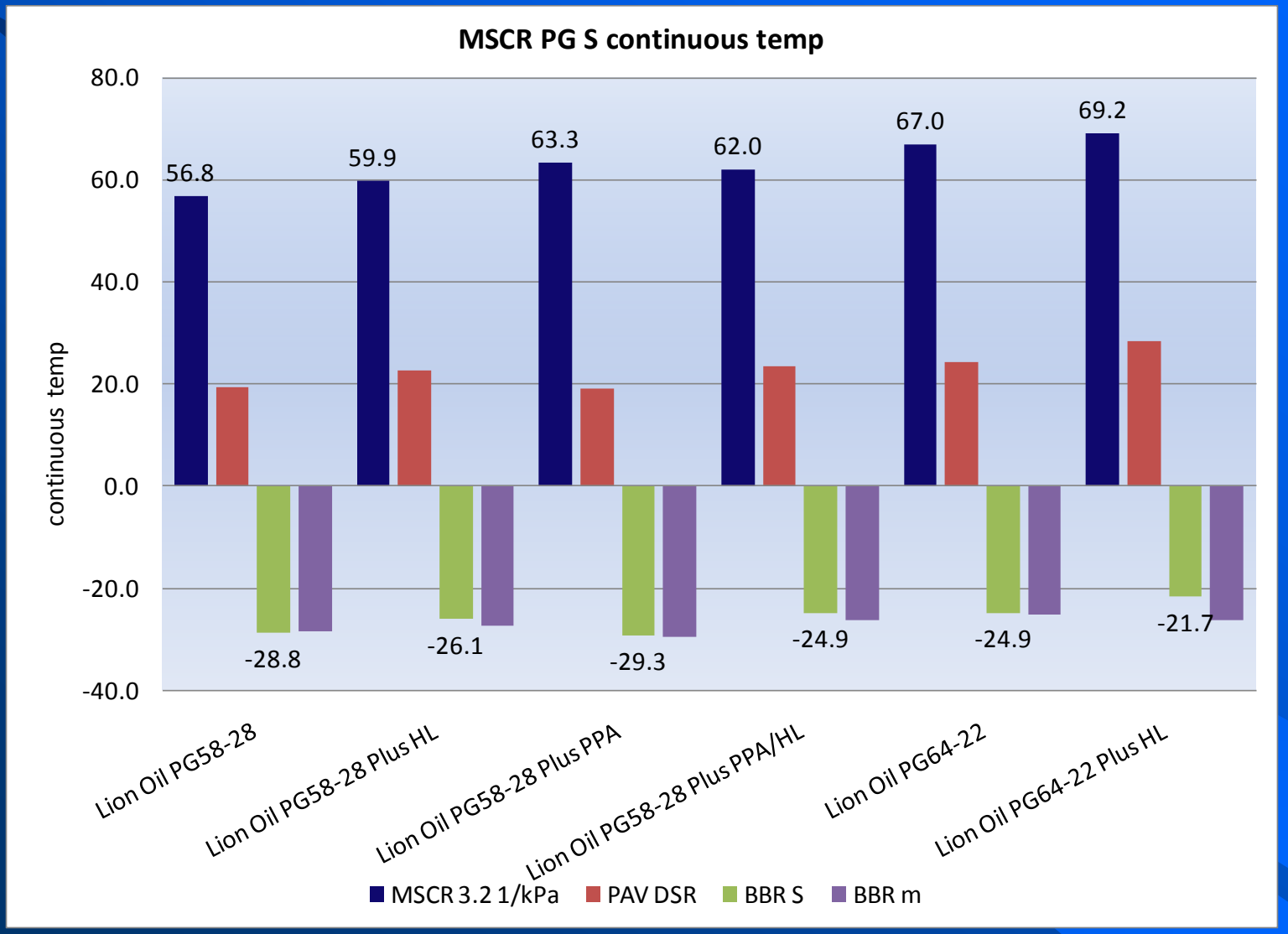
Results of Lime Extraction Study

- The extraction of the lime from the original binder reduced the grade.
- This amount varied from binder to binder.
- In most cases the reduction in grade of PPA modified binder was similar to the reduction of grade of the base asphalt by the lime.

MSCR testing of binder with hydrated lime still in binder

- One binder source Lion Asphalt, 58-28 & 64-22.
  - 1.2% PPA
  - 20% lime by wt 9% by volume.
- Mix binders with Lime, Lime and PPA
- Evaluate binder properties with Lime still in the binder

MSCR test of Lion binder & PPA mixed with hydrated lime as mastic.



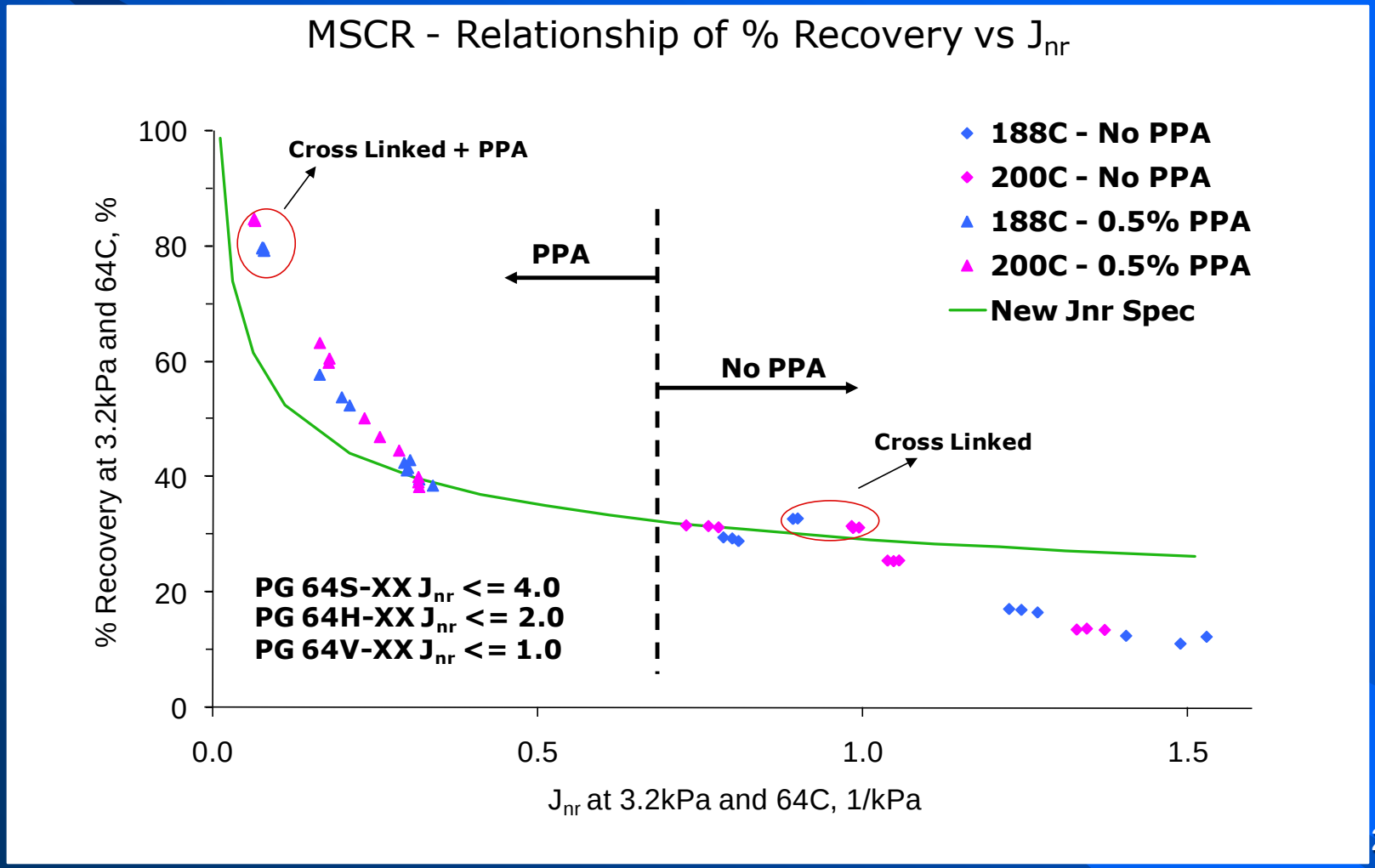
MSCR testing of binder with hydrated lime still in binder

- Lime increased the stiffness of the binder 2 to 3 degrees.
- PPA increased the stiffness of the binder 6 degrees of one full grade.
- The combined lime and PPA only increased the grade 5 degrees. This is less than what would be expected from the combined, but only a 1/3 loss.

Processing and additive study

- One Binder NuStar 58-28
- 3% SBS linear polymer
- 0.5% PPA
- 0.02 % sulfur / % SBS
  - Evaluate MSCR properties of blends of SBS and PPA with different processing procedures, using different mixing temperatures and times.

Relationship of MSCR Jnr and % Recovery to processing and additives



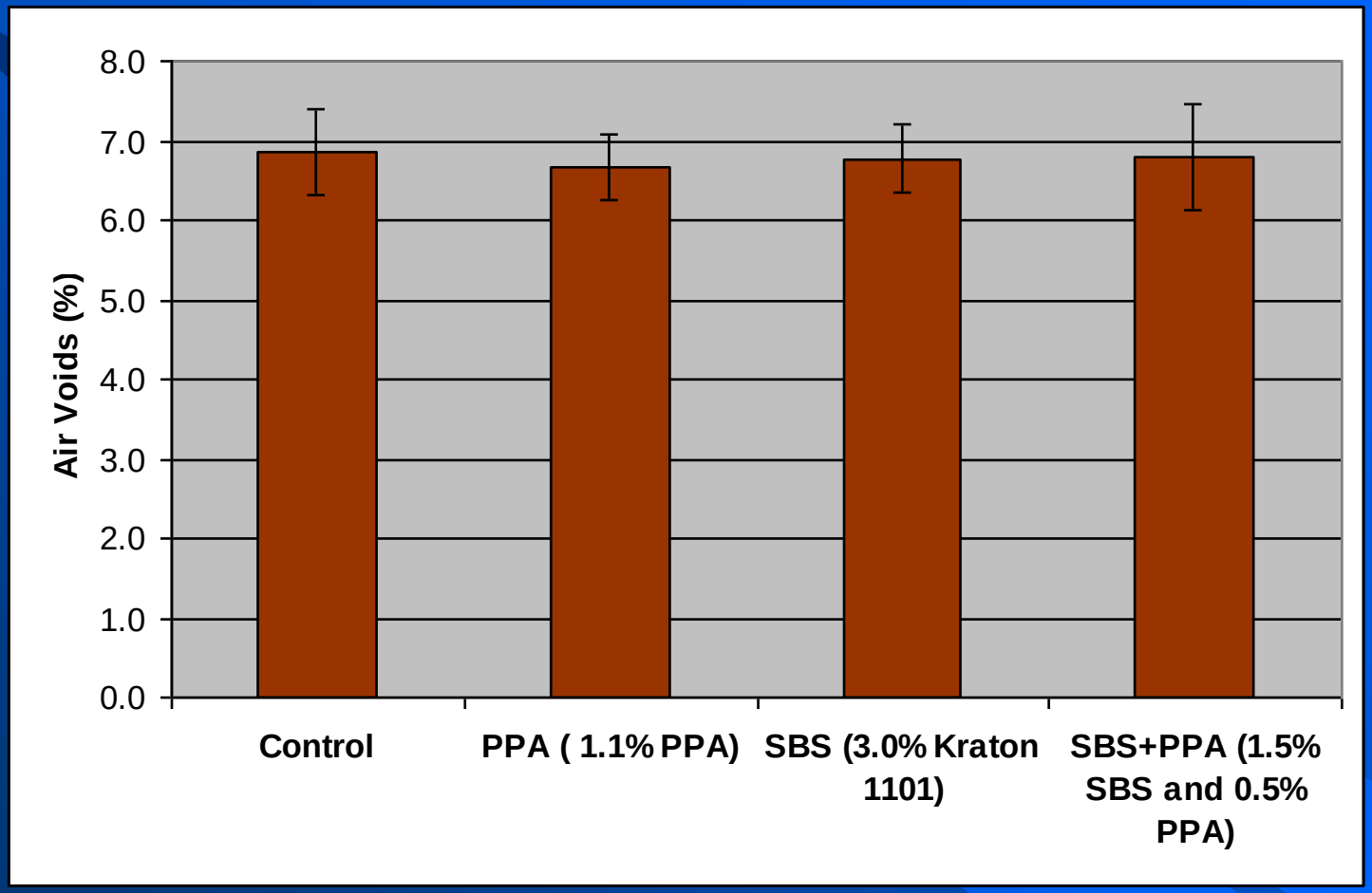
Processing and additive study

- The combined PPA, SBS has a greater effect on the increase in stiffness and elastic response of the binder then either one by its self.
- PPA seems to act as a cross linker as well as a stiffener.

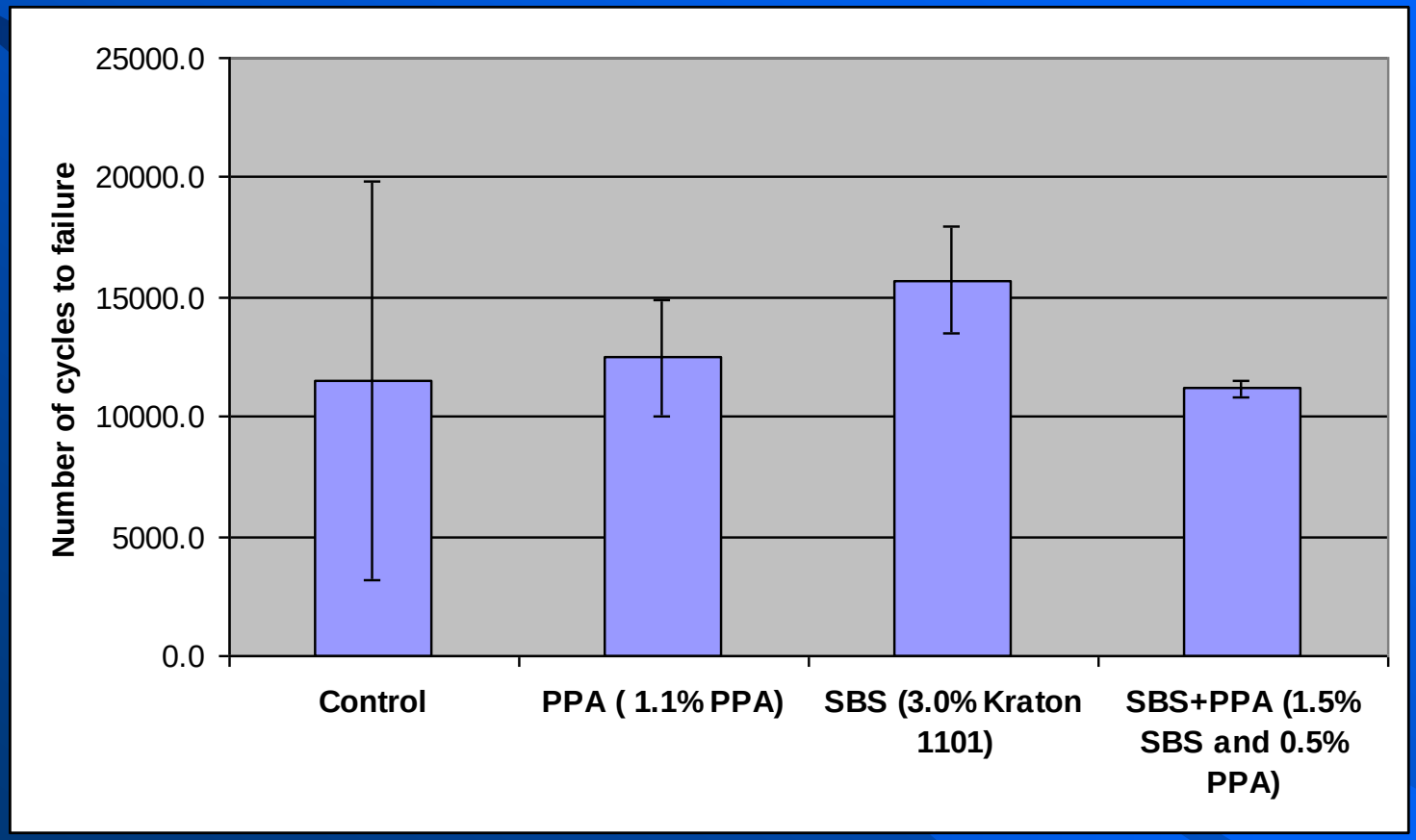
Fatigue Testing

Binder	Lab Ref	Modification	PG Grade
Citgo	B-6362	Control	64
Citgo	B6362	1.1% PPA	76.2
Citgo	B6362	3% Kraton 1101	74.3
Citgo	B6362	1.5% Kraton 1101 + 0.5%PPA	74.6

Air Voids


8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Air Voids (%)
Control
PPA (1.1% PPA)
SBS (3.0% Kraton 1101)
SBS+PPA (1.5% SBS and 0.5% PPA)

Cycles to Failure



PPA Workshop
Fact and Fiction

April 7th and 8th

Minneapolis, MN

Thank You

Questions