Cement

LAFARGE

bringing materials to life

Durability of Portland Limestone Cement

Anna Maria Workshop XII
November 2011

Is the durability of PLC similar to PC?*

- ***What did we look at?***
  - Scaling and Freeze-thaw
    - Field experience
    - "Robustness Testing"
  - Chloride Ion Penetration
  - ASR
  - Sulfate Resistance @ 23C
  - Carbonation
  - Drying Shrinkage

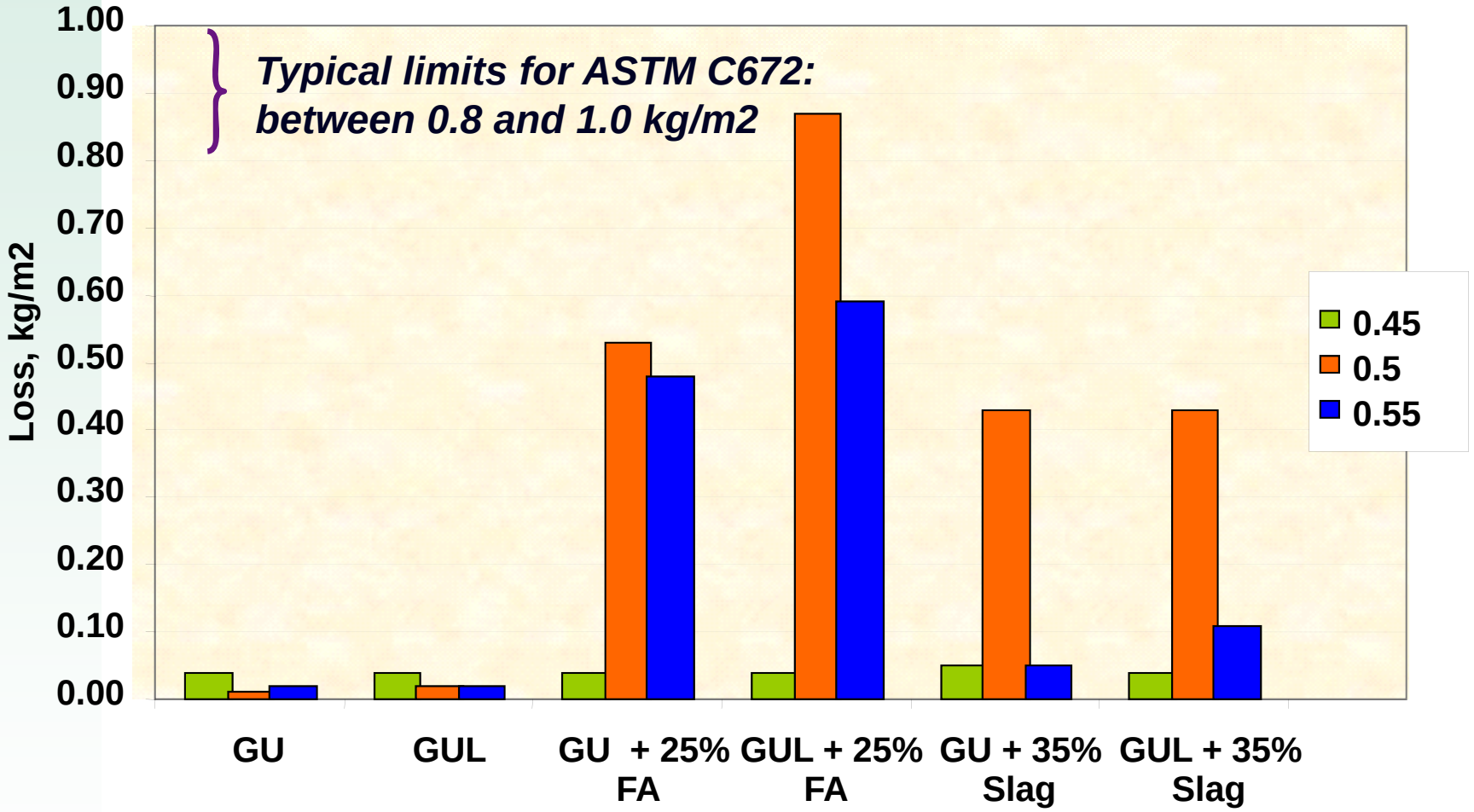
***PLC - Portland Limestone Cement, PC - Portland Cement**
GUL - General Use Limestone Cement, GU - General Use Cement

Robustness Testing - Scaling and Freeze/Thaw

- Objective:
  - Assess the sensitivity of PLC compared to PC when subjected to extreme conditions
- Scaling
  - Water/Binder ratio of 0.45, 0.50 and 0.55
  - Lab and field testing
  - 25% FA* and 35% slag
- Freeze-Thaw
  - Water/Binder ratio of 0.74, 0.80 and 0.90
  - 20% FA* and 35% slag

FA* - Type F

Scaling – Lab Results - ASTM C672



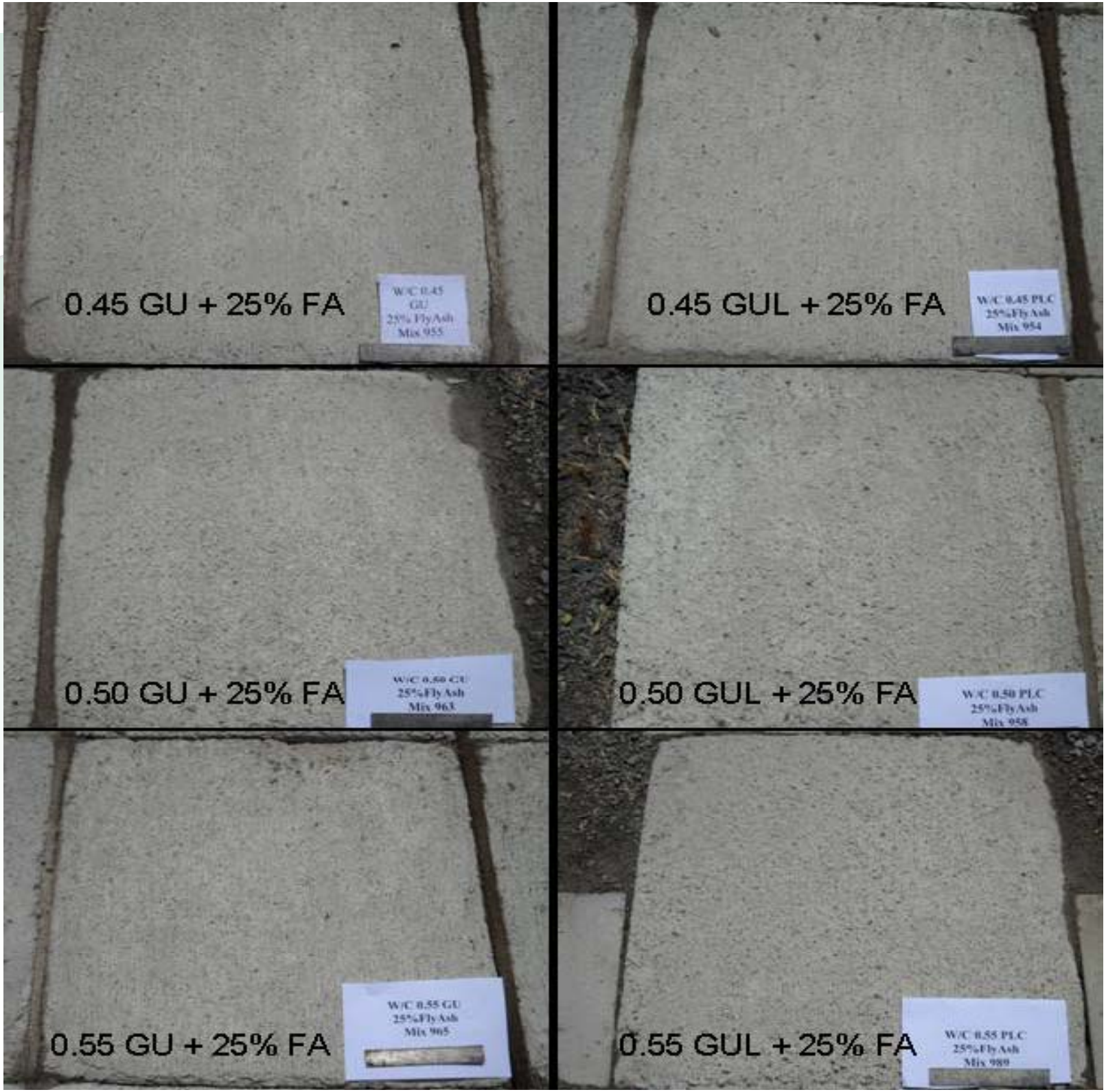
- *Lab scaling results tend to indicate impact of w/c*

No measurable difference between GU and GUL

Scaling – Field Tests





Scaling

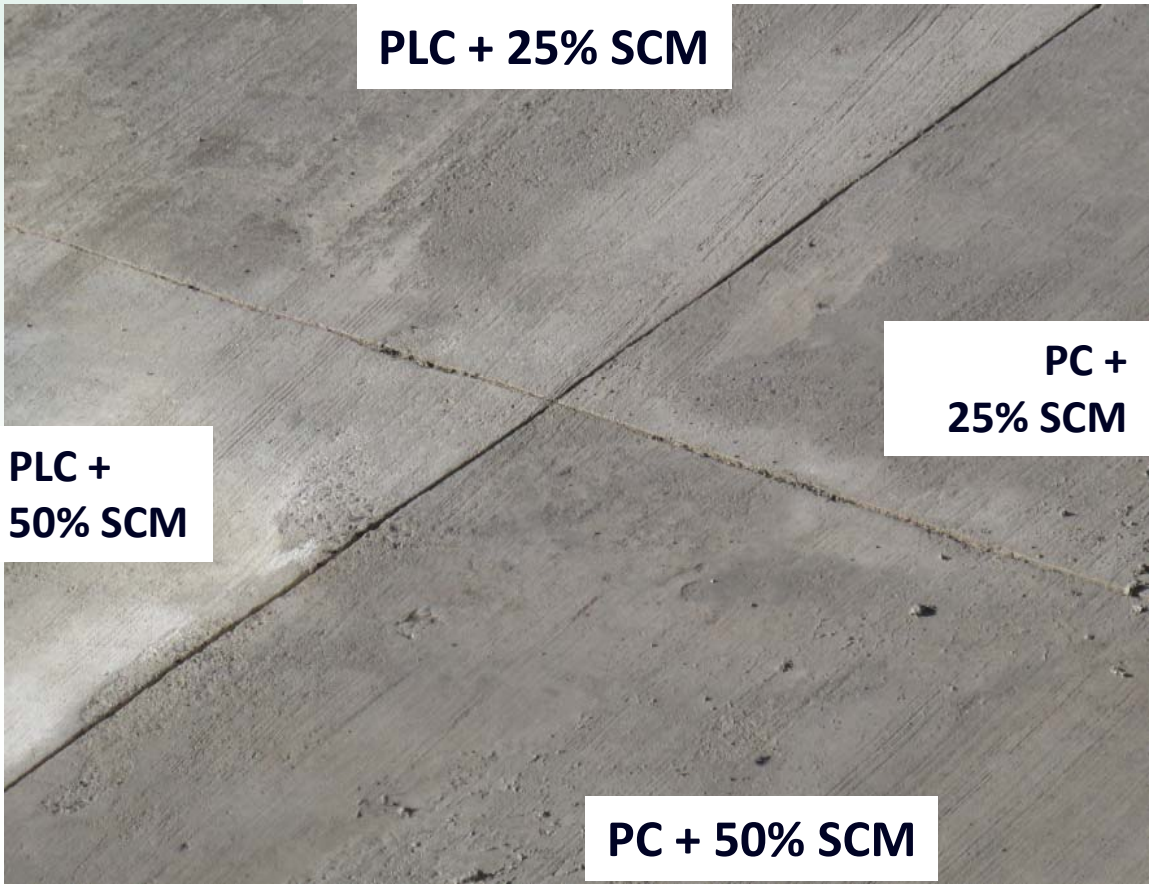
- Field results after 1 year (only showing the FA slabs)

No significant difference between GU and GUL

Scaling – Field Trials

- **Three field trials concluded;**
  - Good performance of GUL with up to 50% SCM
  - **No significant difference between GU and GUL mixes**

After 2 winters



Parking lot in Gatineau

- Anna Maria workshop X (2009)
- Concrete International (2010)

+ 2 Paving projects - Brookfield and Exshaw

Journal of Pavement and Research Technology (2010)

***SCM** - Optimized blend of slag and C ash*

Freeze-Thaw C666-A

	w/b = 0.74		
	DF, %	Length Change, µm/m	Weight Loss, %
GU	99	28	-4.43
GUL	100	24	-4.11
GU + 20% FA	100	12	-2.88
GUL + 20% FA	100	8	-3.63
GU + 35% Slag	95	10	-3.17
GUL + 35% Slag	97	8	-2.45

	w/b = 0.80		
	DF, %	Length Change, µm/m	Weight Loss, %
GU	98	24	-4.43
GUL	99	22	-5.11
GU + 20% FA	95	27	-6.09
GUL + 20% FA	99	7	-5.39
GU + 35% Slag	95	5	-4.81
GUL + 35% Slag	96	42	-4.25

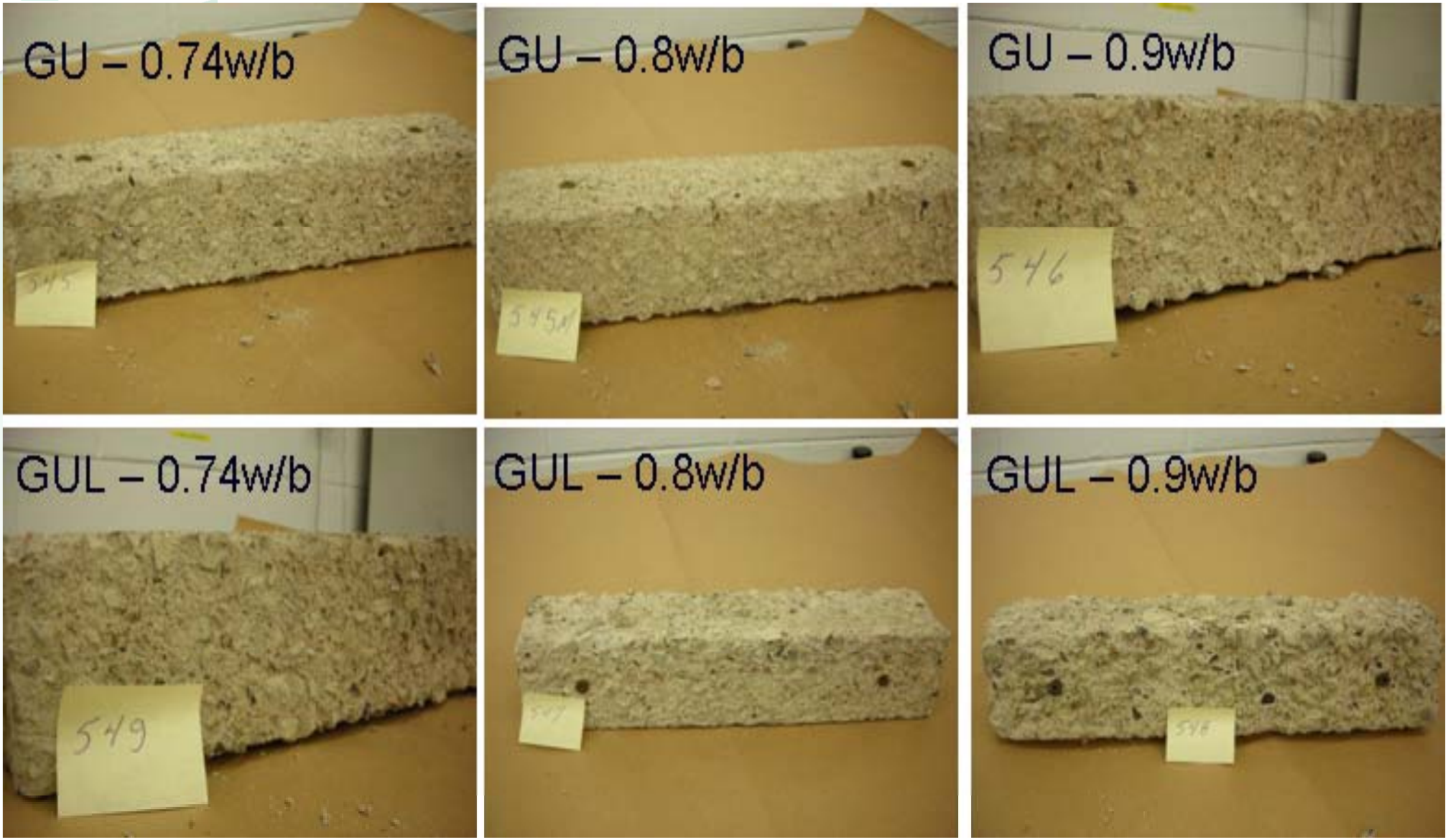
	w/b = 0.90		
	DF, %	Length Change, µm/m	Weight Loss, %
GU	99	22	-5.56
GUL	94	22	-9.93
GU + 20% FA	95	17	-9.4
GUL + 20% FA	100	7	-9.74
GU + 35% Slag	96	10	-4.43
GUL + 35% Slag	96	7	-5.18

- **Durability Factor good**
- **Little expansion…**
- **…. but scaling of the bars, especially with the higher W/C**

(see next slide)

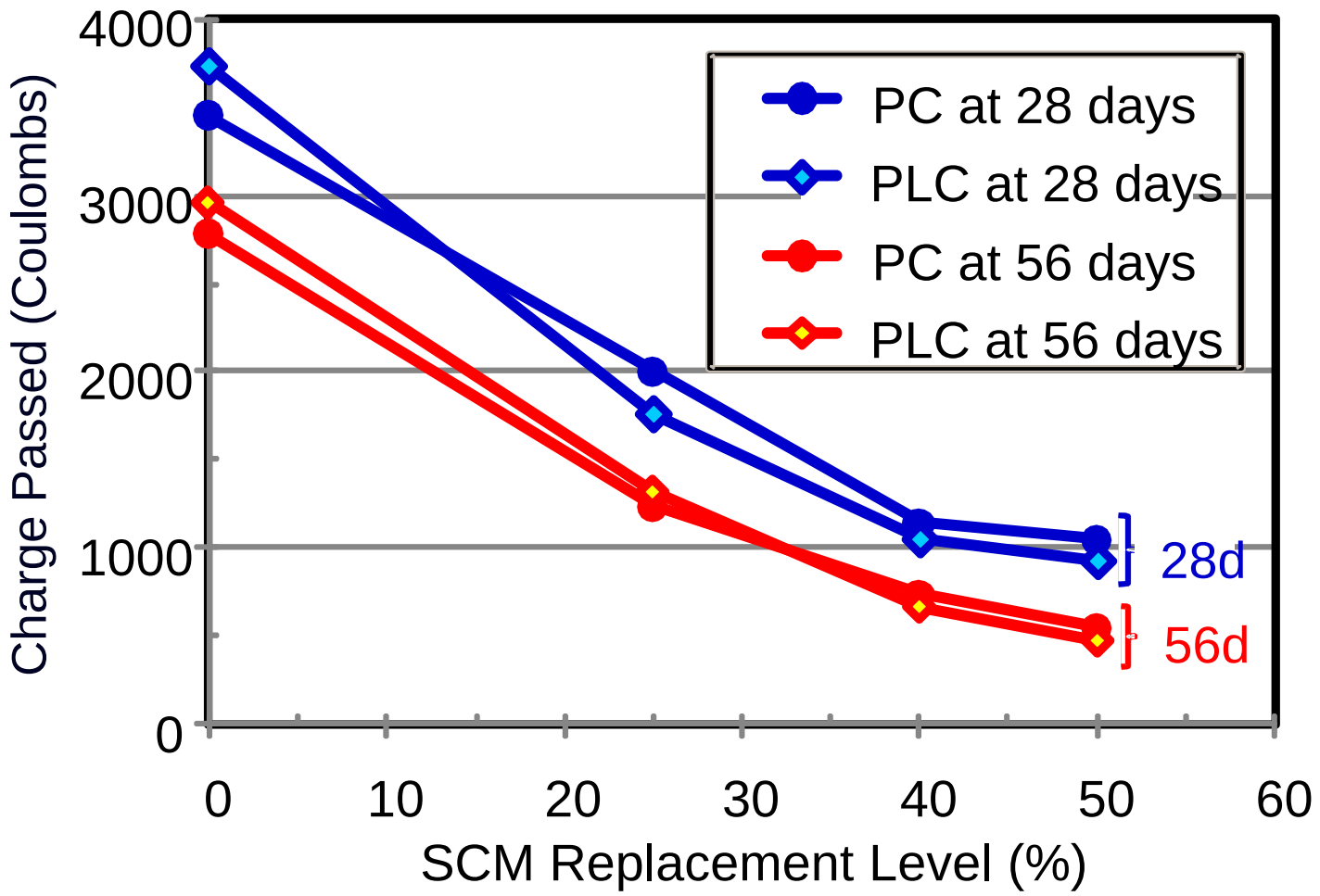
No measurable difference between GU and GUL

Freeze-Thaw C666-A



No significant difference between GU and GUL

Chloride Penetration – RCPT – Field Samples

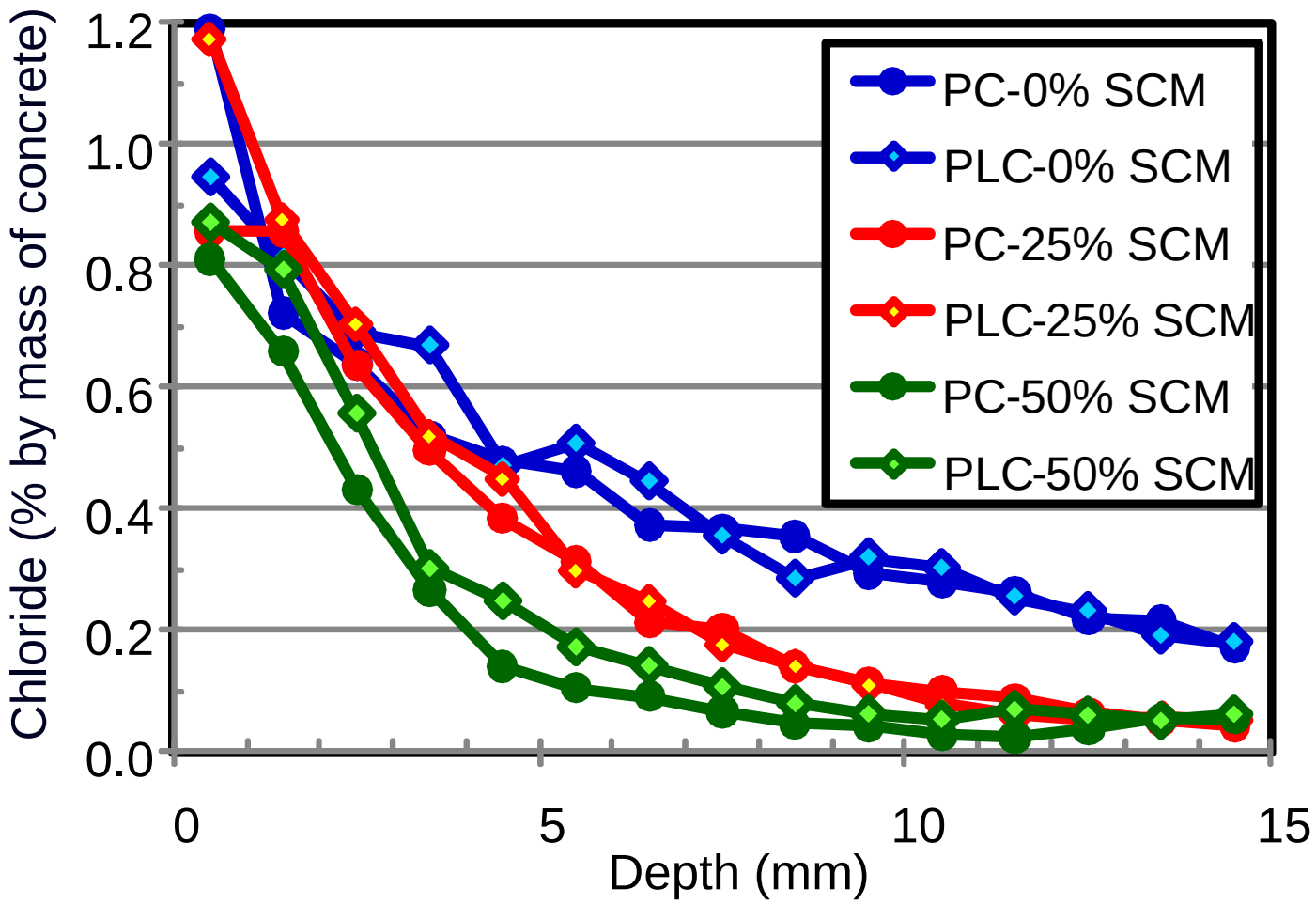


No measurable difference between PC and PLC

Results from Gatineau Trial (Concrete International, Jan 2010)

SCM *- Optimized blend of slag and C ash*

Chloride Penetration Profiles - Field Samples



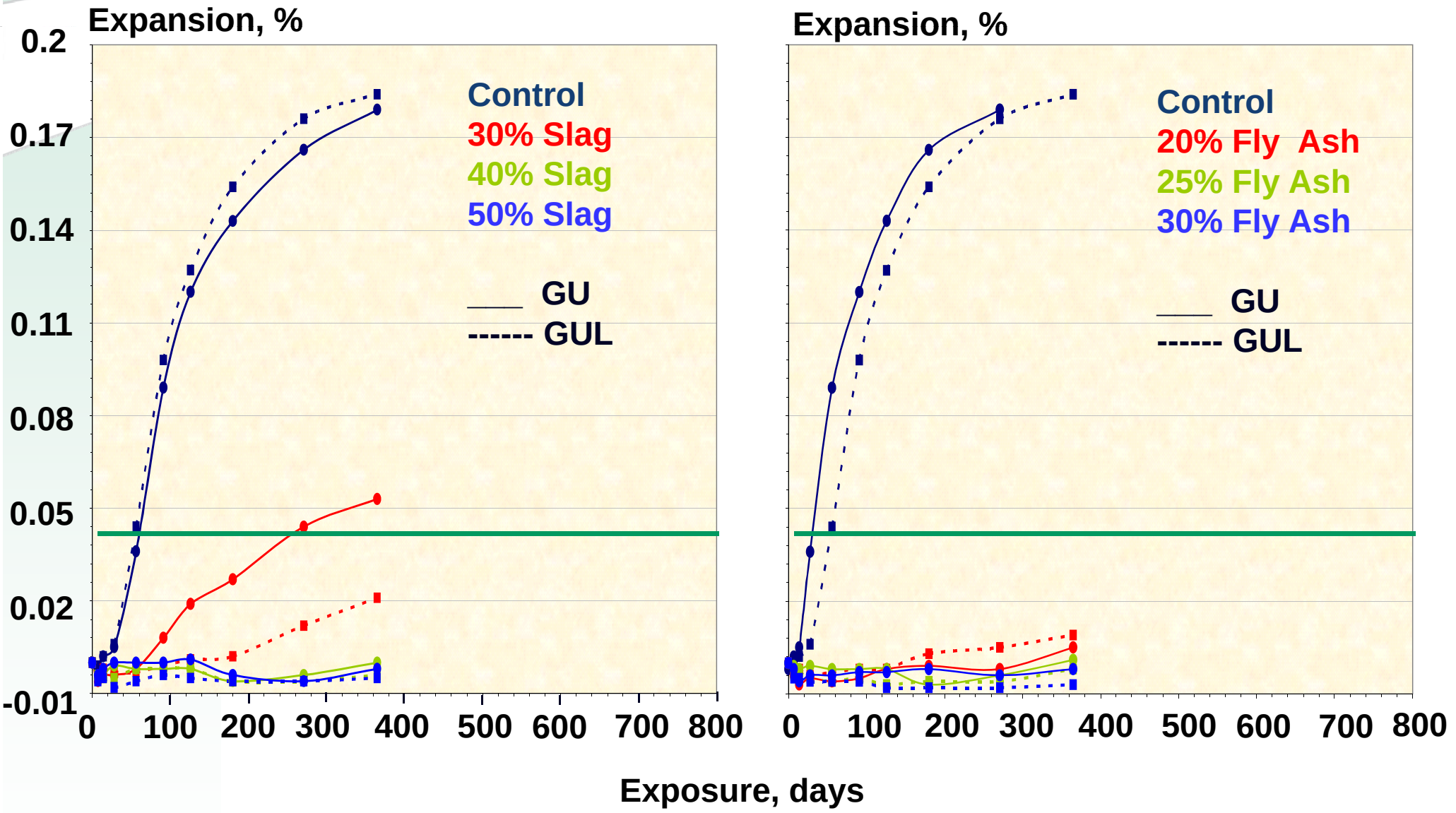
No measurable difference between PC and PLC

Chloride Profiles for Cores taken at 35 Days and Immersed in NaCl solution for 42 Days

Results from Gatineau Trial (Concrete International, Jan 2010)

SCM - *Optimized blend of slag and C ash*

ASR – Concrete Prism Test 38ºC

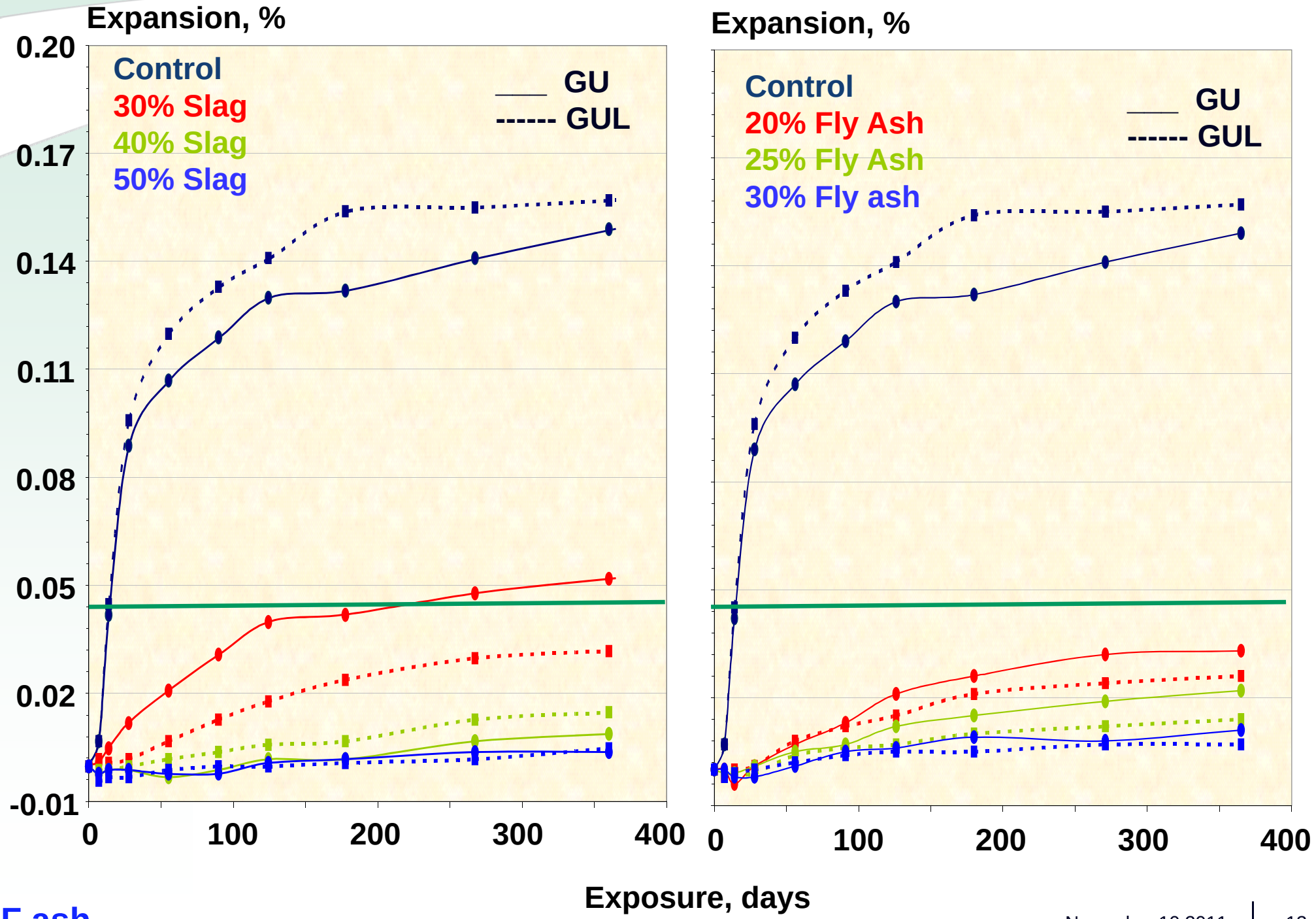


No significant difference between GU and GUL

Similar results for concrete prism tests @ 60ºC and mortar bar tests (see next 2 slides)

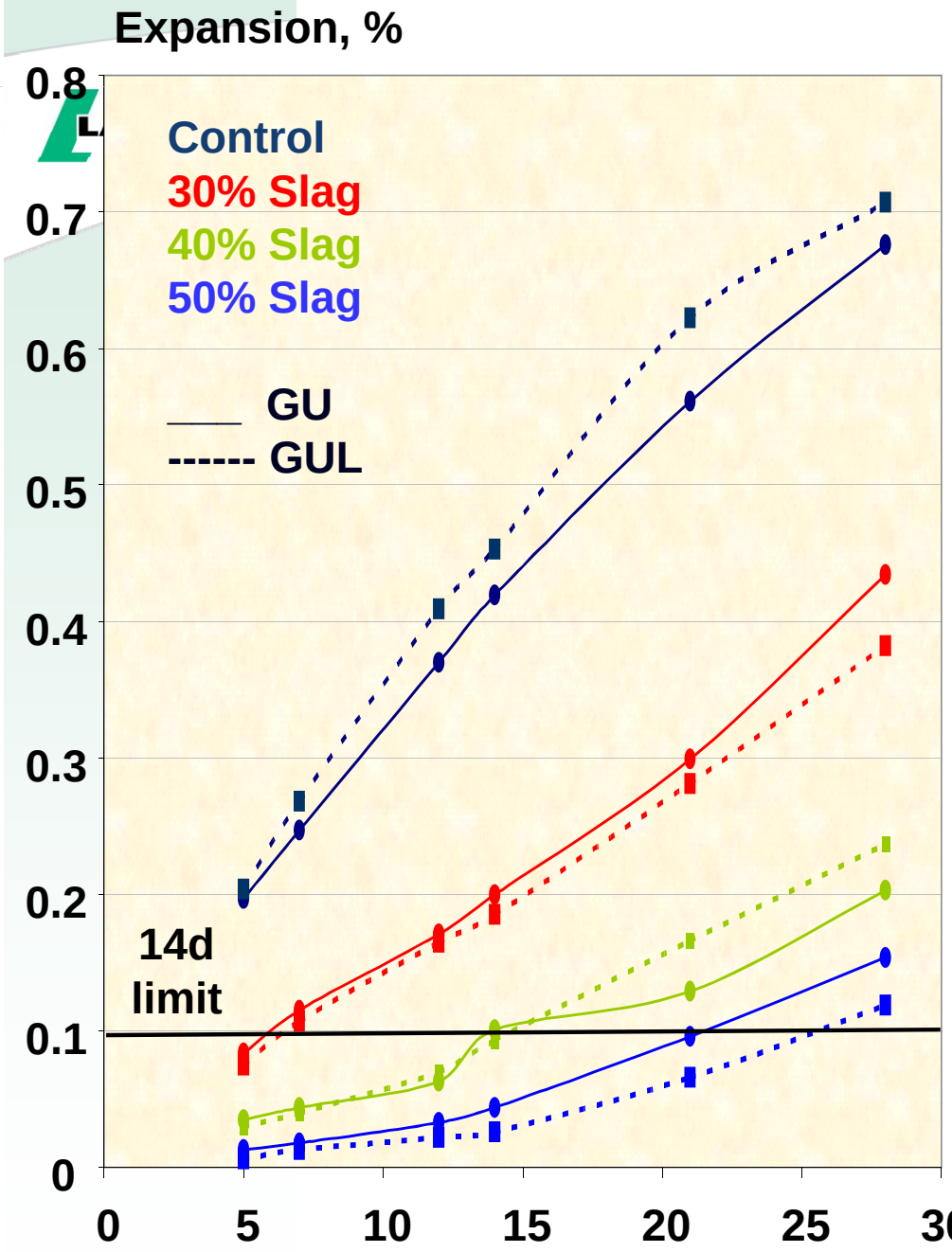
F ash

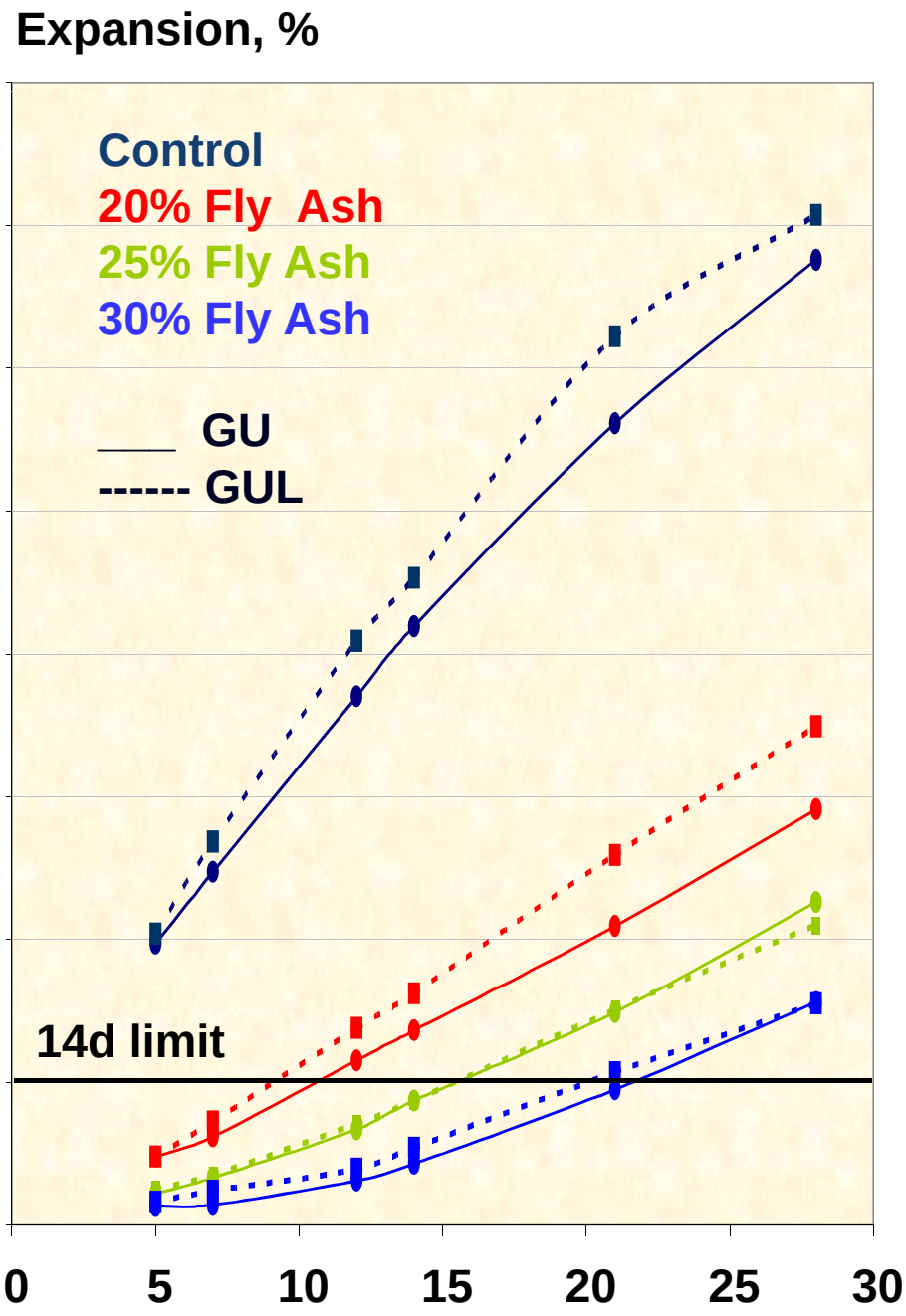
ASR - **Concrete Prism Test 60C**



F ash

ASR - Accelerated Mortar Bar Test





Exposure, days

F ash

Carbonation – 1 year results

Carbonation Depth, mm

Mix - w/c 0.45	1d curing	3d curing	7d curing
GU	5	2	1
GUL	5	2	1
GU + 40% FA	11	5	5
GUL + 40% FA	10	5	5
GU + 60% Slag	9	5	4
GUL + 60% Slag	10	3	3
Mix - w/c 0.55			
GU	7	4	2
GUL	7	4	3
GU + 40% FA	15	10	7
GUL + 40% FA	15	10	10
GU + 60% Slag	15	8	7
GUL + 60% Slag	15	10	8

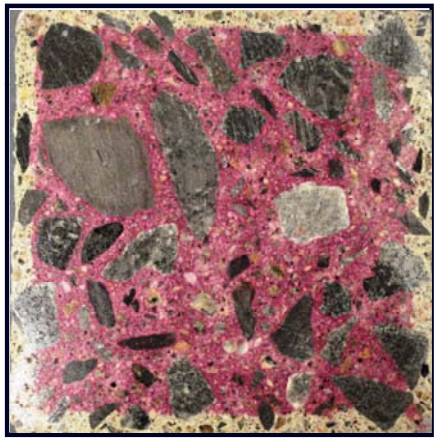
- *Curing, w/b ratio and SCMs had an impact on carbonation depth*

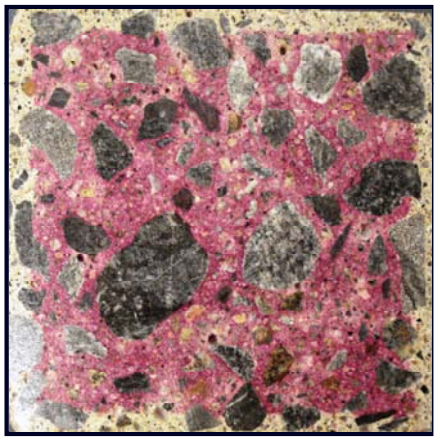
No significant difference between GU and GUL

Samples kept at 23ºC – 65% RH

Carbonation – 1 year results
- 0.55 w/b
- 3d curing

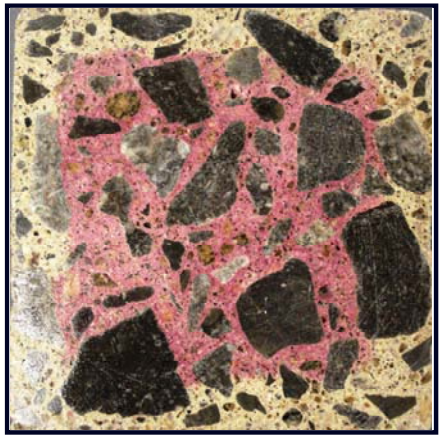
GU

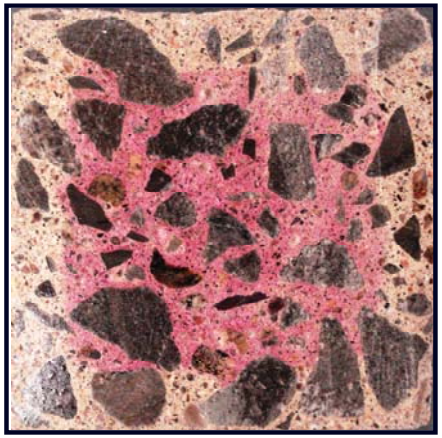




GUL

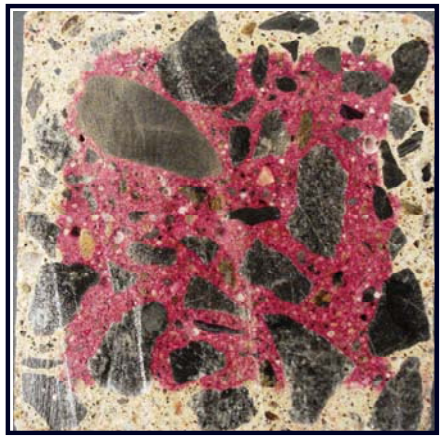
GU + 40% FA





GUL + 40% FA

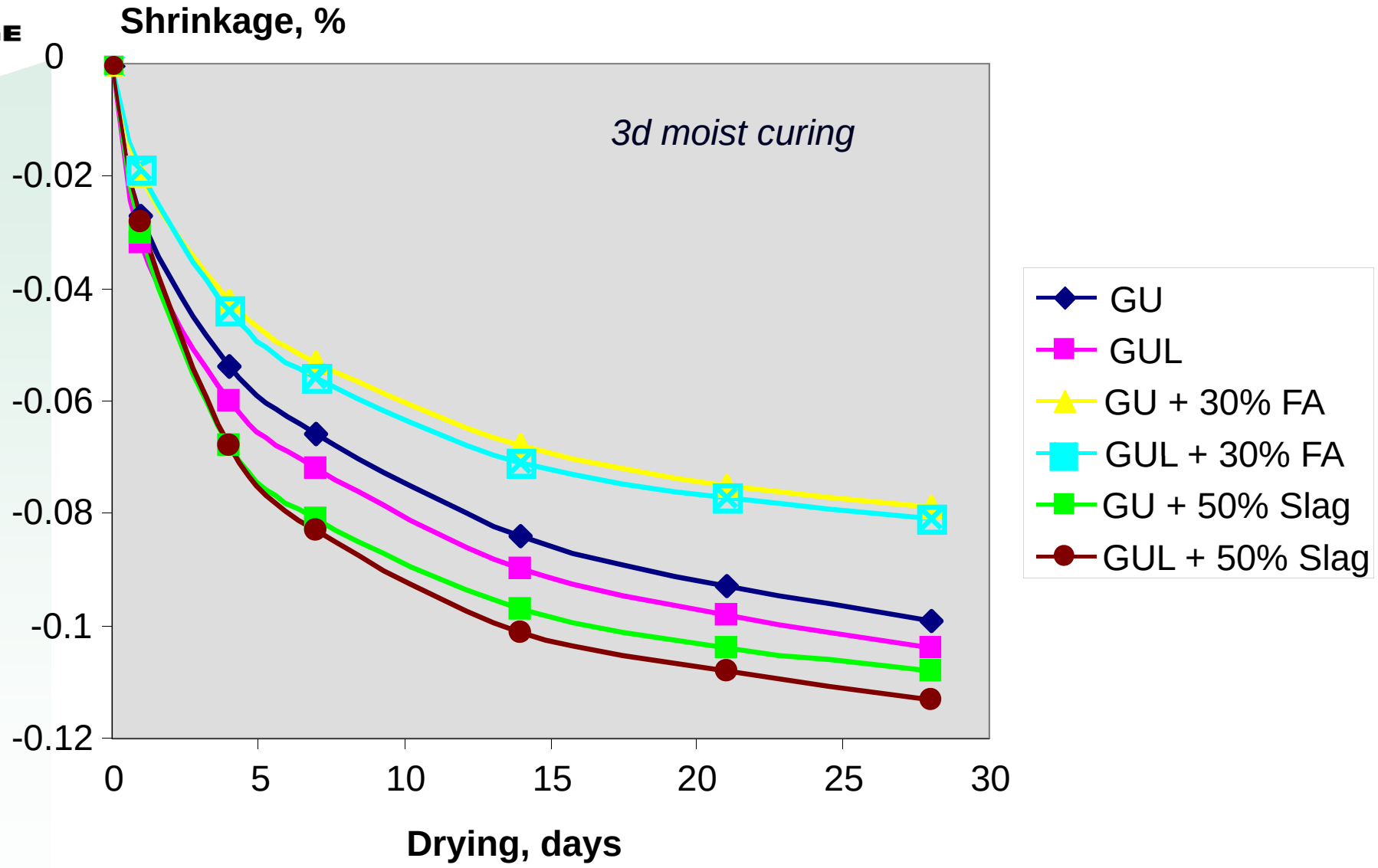
GU + 60% Slag



GUL + 60% Slag

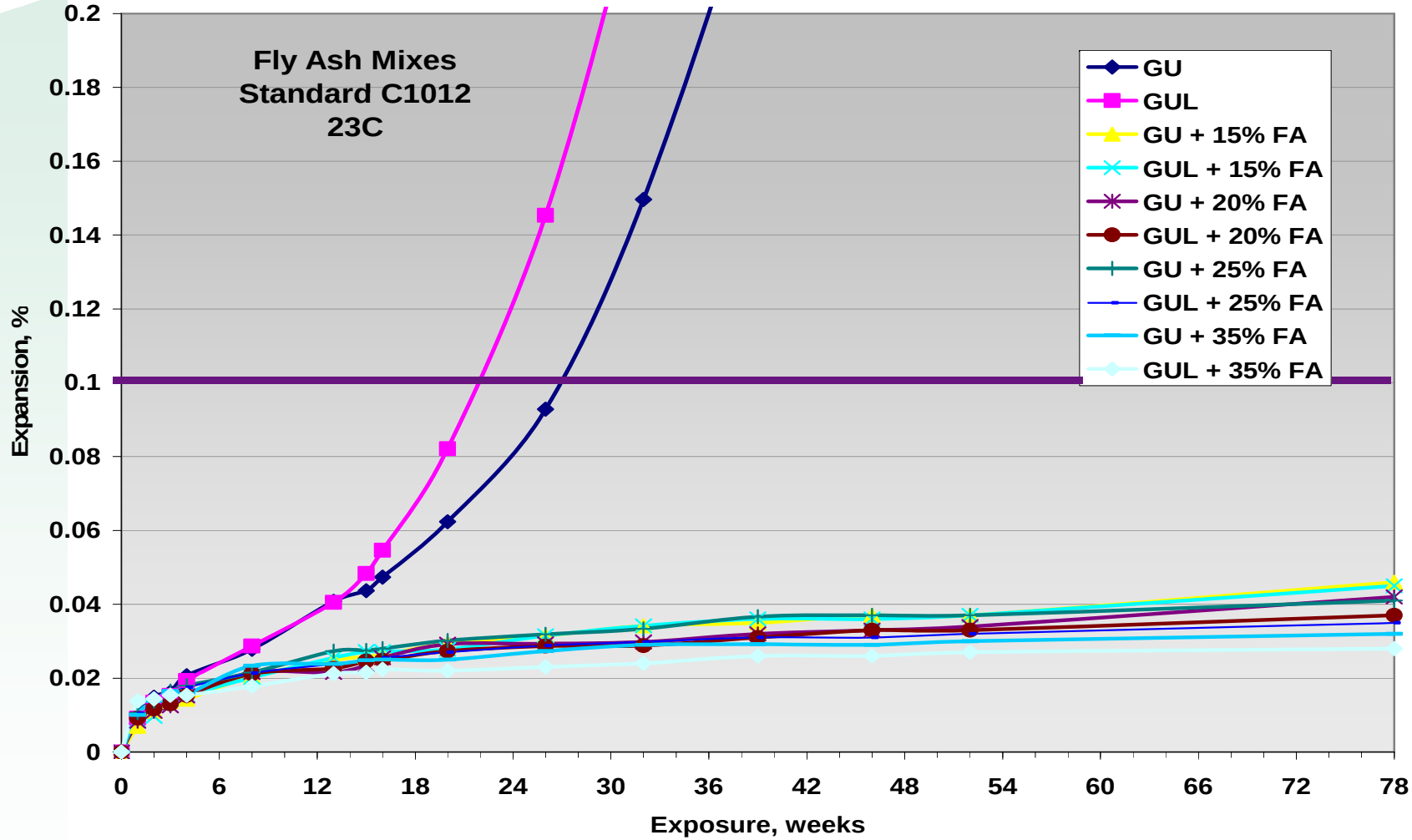
No significant difference between GU and GUL

Mortar Drying Shrinkage ASTM C596



No significant difference between GU and GUL

Sulfate Resistance C1012 @ 23C



- *Also tested with slag, SF and ternary systems @ 23C - All mixes show little expansion (< 0.1%) after 18 months of exposure, except for the control mixes (GU and GUL)*

No measurable difference between GU and GUL

FA* - Type F

Summary

There is no measurable difference between PLC and PC, with respect to durability in the following areas;

- **Scaling**
- **Freeze/thaw**
- **Chloride ion penetration**
- **ASR**
- **Carbonation**
- **Shrinkage**
- **Sulfate resistance @ 23C**