CEMENT DIVISION

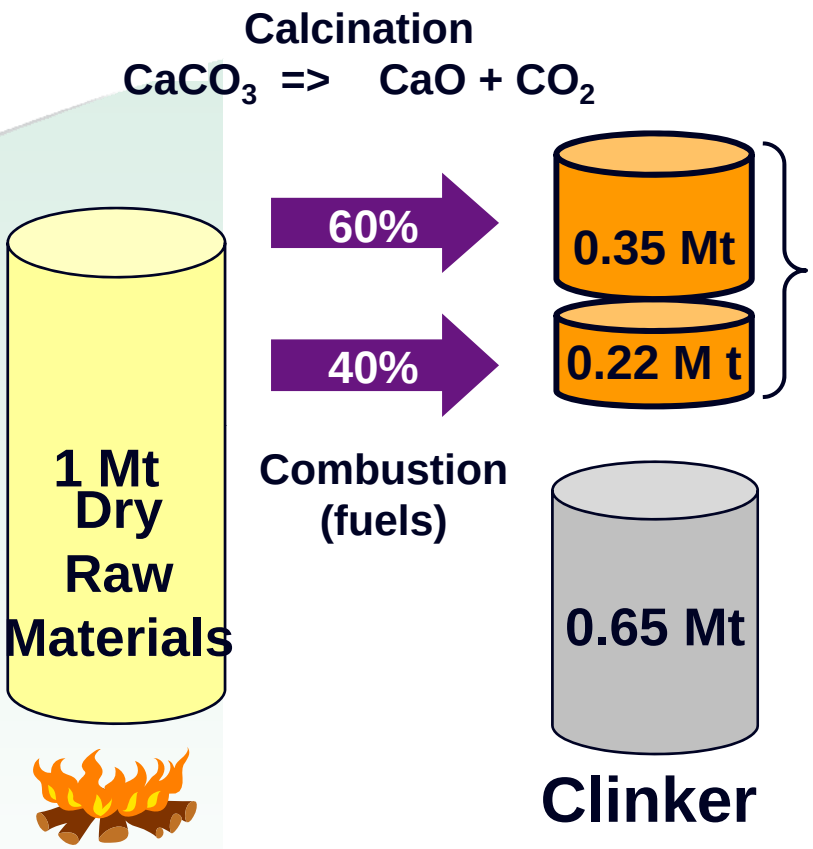
LAFARGE

bringing materials to *life*

Portland Limestone Cement

November 5, 2009
Anna Maria Workshop

Levers to Reduce CO_2



- **Levers to reduce CO2 emmissions**
  - Improve efficiency of assets
  - Alternate fuels (biomass)
  - Alternate raw materials (e.g. steel slag)
  - Clinker reactivity (to allow more SCMs)
  - Reduce clinker production
  - Blended/limestone cements (increase C/K ratio)

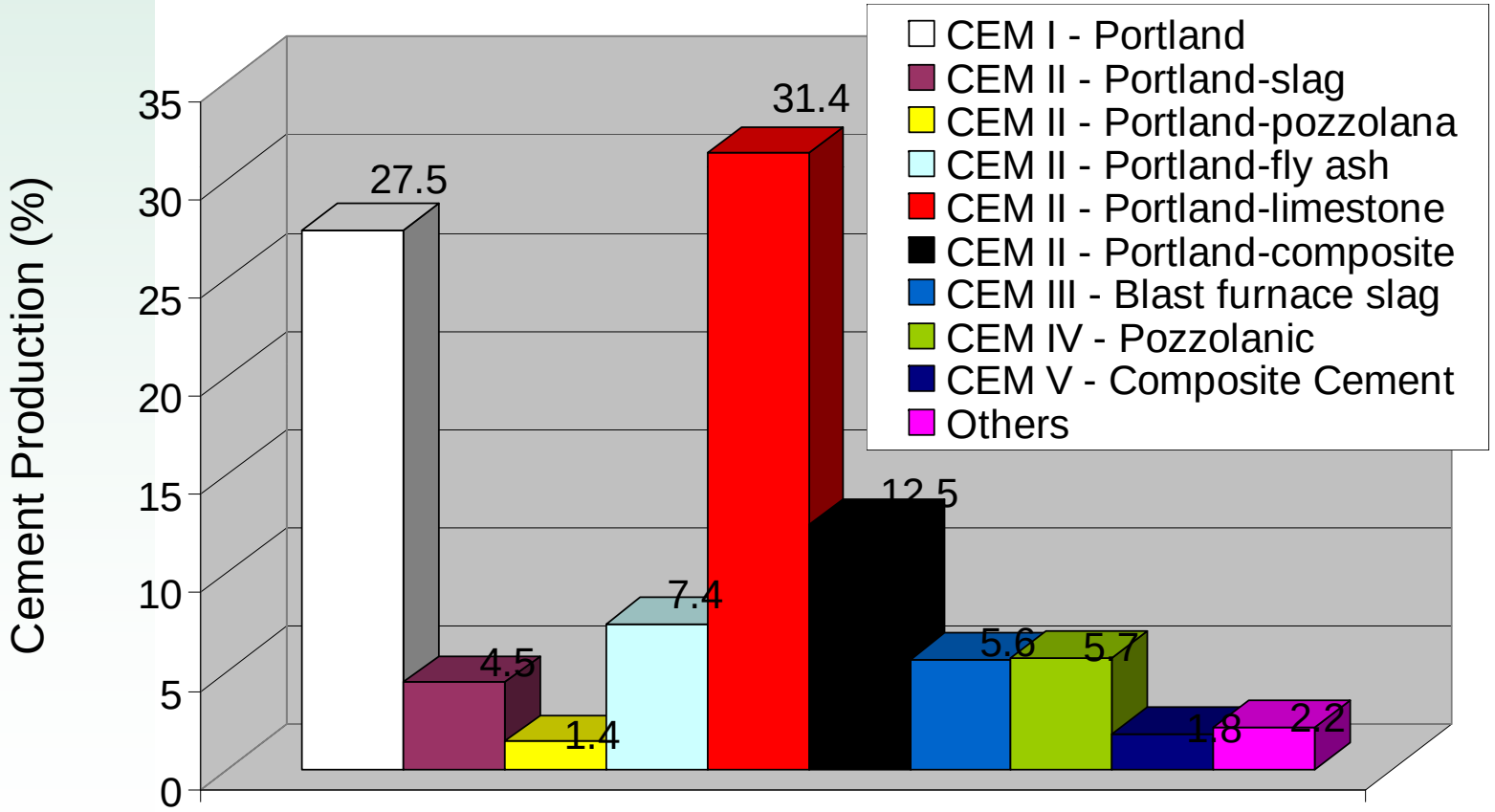
1 t of KK ~ 0.88 t of CO_2

Development of Limestone Cement in Canada

- The Canadian Standards Association (CSA A3001-08) now permits the inclusion of up to 15% limestone in four types of Portland limestone cement:
  - GUL – General Use Cement
  - MHL – Moderate Heat of Hydration Cement
  - LHL – Low Heat of Hydration Cement
  - HEL – High Early-Strength Cement
  - *Not allowed for sulfate resisting cement*

Evolution of PLC in Europe

Cements Produced in Europe in 2004 (according to Cembureau) PLC – up to 35% limestone



Manufacture of PLC

- Limestone Cement has been developed to exhibit **"equivalent performance"** compared to GU cement

- Performance to-date has been equivalent
  - Equivalent initial reactivity (set time, 1-day)
  - Equivalent 28-day strength
  - Equivalent durability (freeze/thaw, salt scaling, etc.)

- Equivalent performance is achieved by optimizing the PLC with regards to composition and psd, and requires intergrinding rather than blending
  - Limestone fineness in the interground product is significantly finer than the clinker fraction
  - PLC fineness higher than Portland cement as well as the 45 microns

PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October 6, 2008

- Objective:
  - Field test performance of PLC concrete with various levels of SCM in an exterior flatwork application
  - Control sections with type GU + SCM

Eight Concrete Mixes:

Cement	NewCem Plus Replacement Level (%)			
	0	25	40	50
Type GU	x	x	x	x
Type GUL	x	x	x	x

Cementing Materials:

- Type GU with 3.5% limestone (PC)
- Type GUL with 12% limestone (PLC)
- NewCem Plus = Optimized blend of slag and ash

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Eight Concrete Mixes:

Cement	NewCem Plus Replacement Level (%)			
	0	25	40	50
Type GU	92	69	55	46
Type GUL	84	63	50	42

KK content

Cementing Materials:

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- Type GUL with 12% limestone (PLC)
- NewCem Plus = Optimized blend of slag and ash

PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October 6, 2008

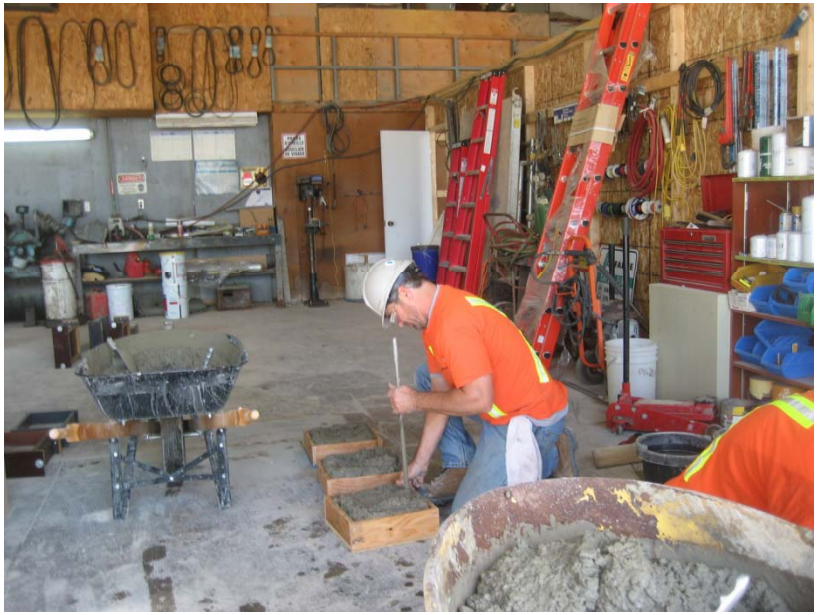
- Fresh Concrete Properties:
  - Slump, Air, Temperature, Density

Hardened Concrete Properties on site-cast specimens:

- Strength
- RCPT
- Air-Void Parameters, Freeze-thaw
- Salt Scaling (ASTM C672 & BNQ Method)

Properties of 35-Day-Old Cores:

- Strength
- RCPT
- Chloride Ion Diffusion Coefficient



PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October 6, 2008

Properties of Plastic Concrete

SCM (%)	Cement Type	W/CM	Slump (mm)	Air (%)	Temp (°C)	Unit Wt. (kg/m^3)
0	PC	0.45	100	6.8	18.8	2317
	PLC	0.44	80	6.0	17.5	-
25	PC	0.44	75	6.2	18.1	2317
	PLC	0.45	100	6.6	16.3	2328
40	PC	0.44	95	6.8	16.5	2303
	PLC	0.44	80	6.0	15.5	2331
50	PC	0.44	95	6.8	15.0	2300
	PLC	0.44	95	6.5	14.5	2309

PLC Trial Pour at Gatineau Ready-Mixed Concrete Plant – October 6, 2008

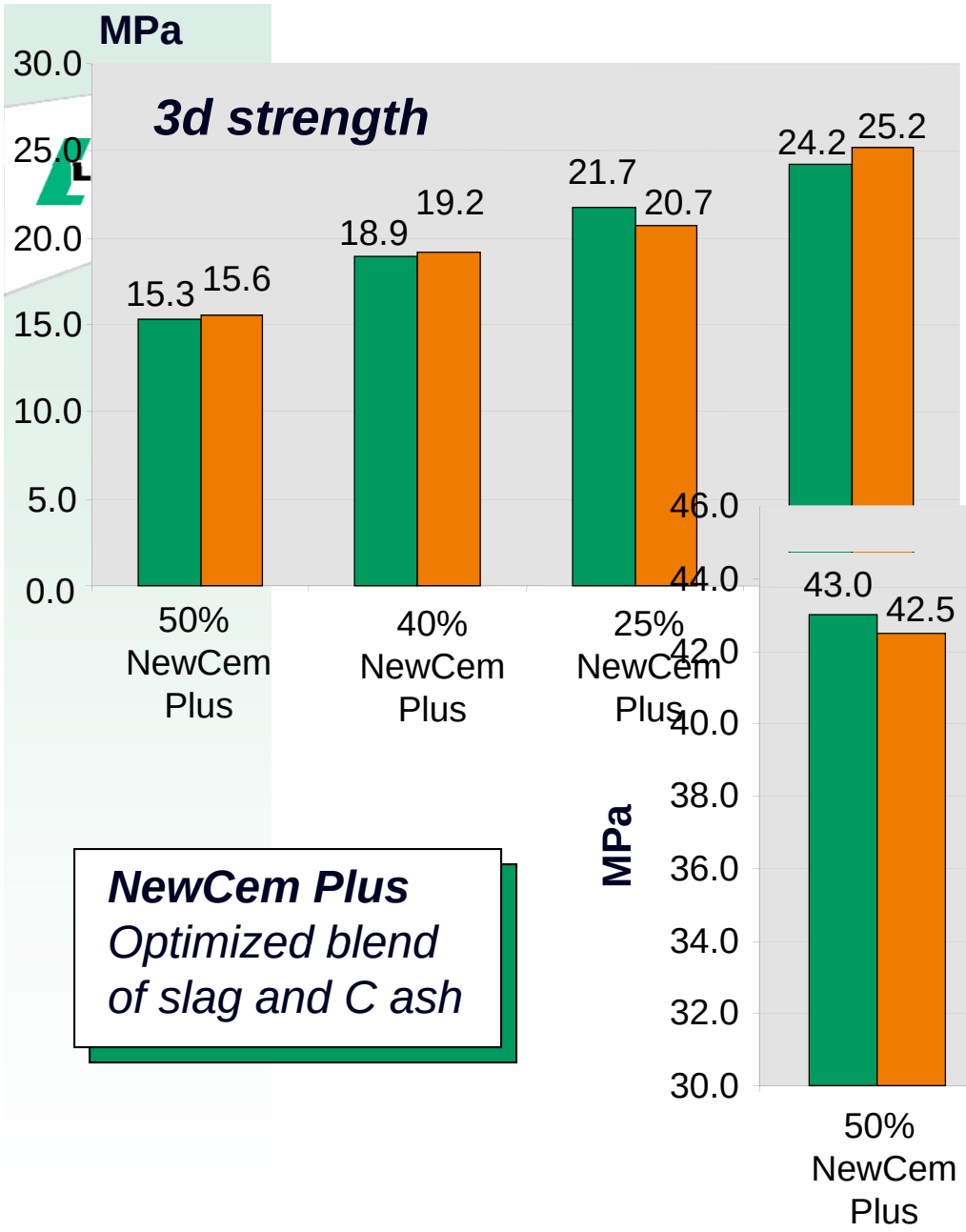
Vibrating Screed

Bullfloat

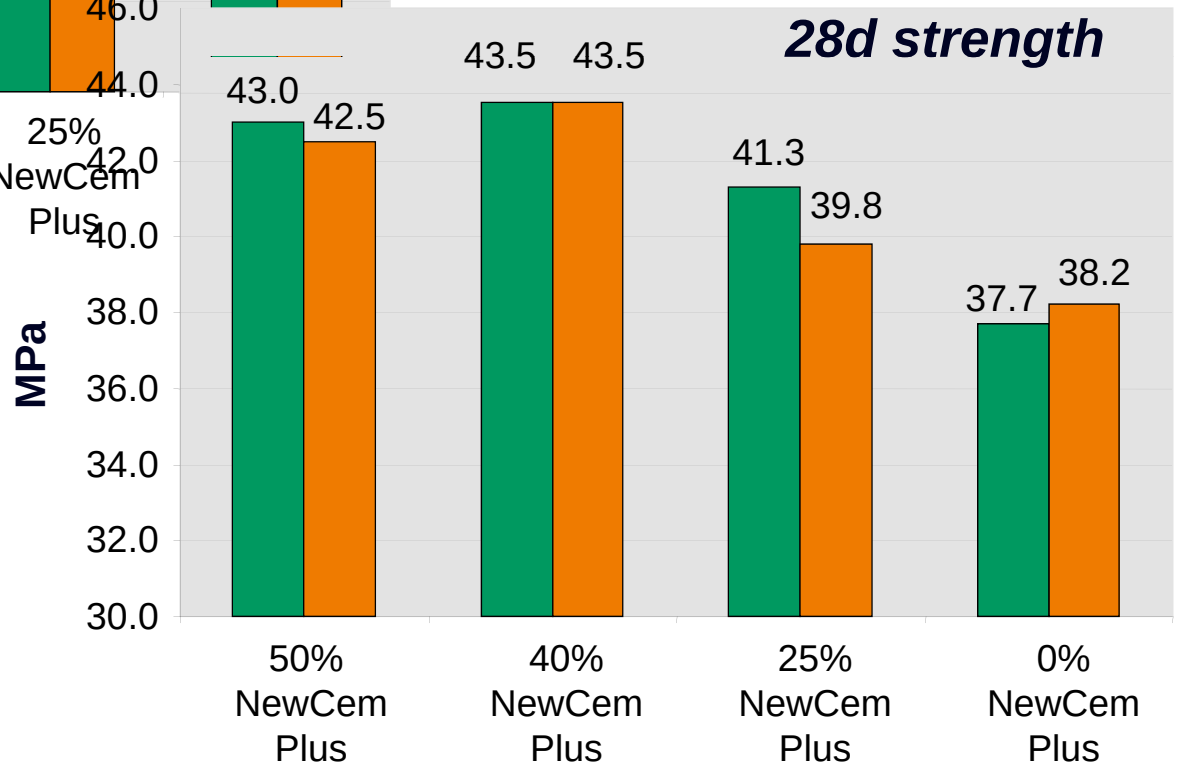
Broom Finish

Insulated Tarps (except slab 5)

Strength Comparison
GU vs PLC Mixes

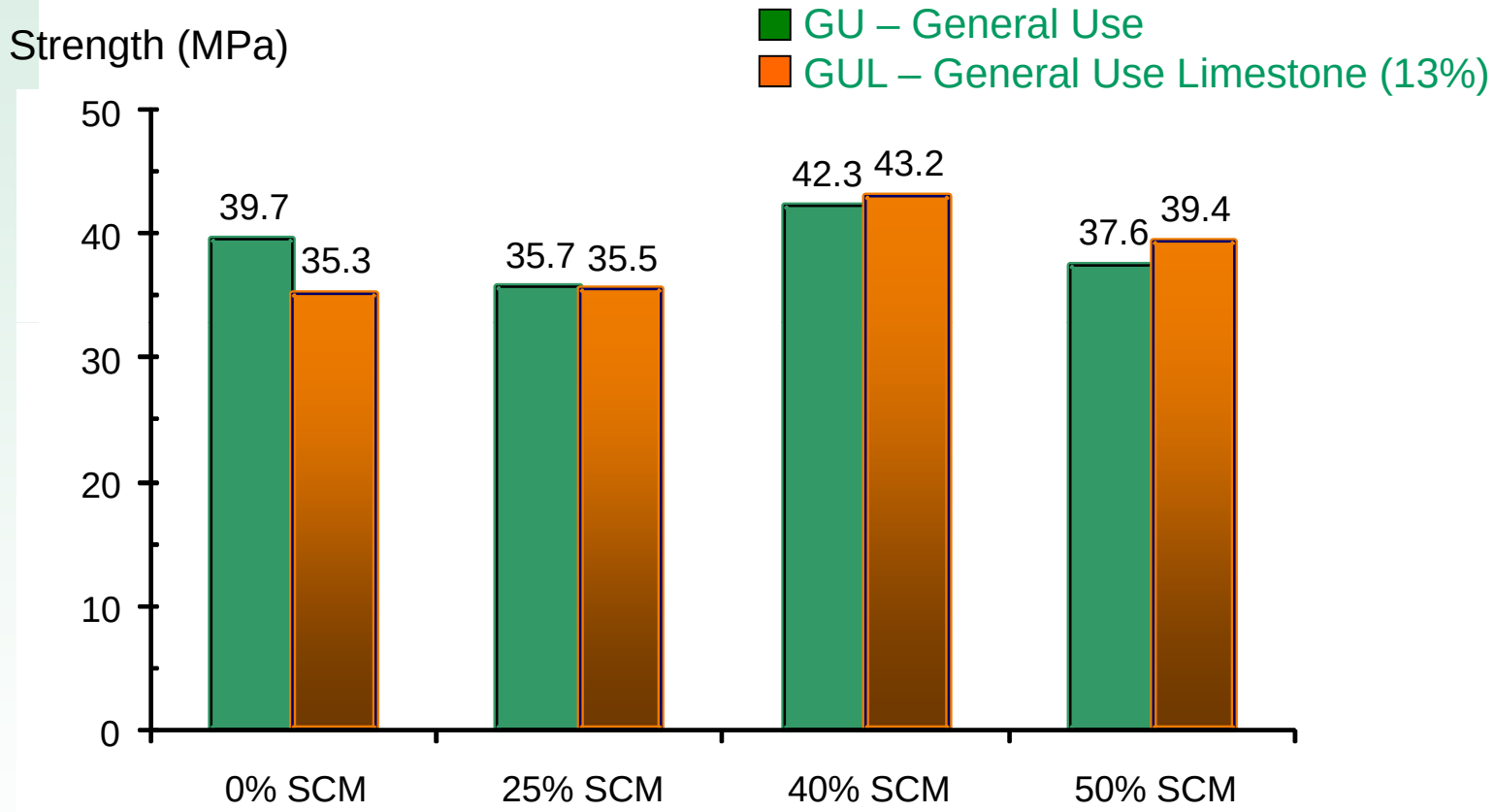


GU – General Use
GUL – General Use Limestone (13%)



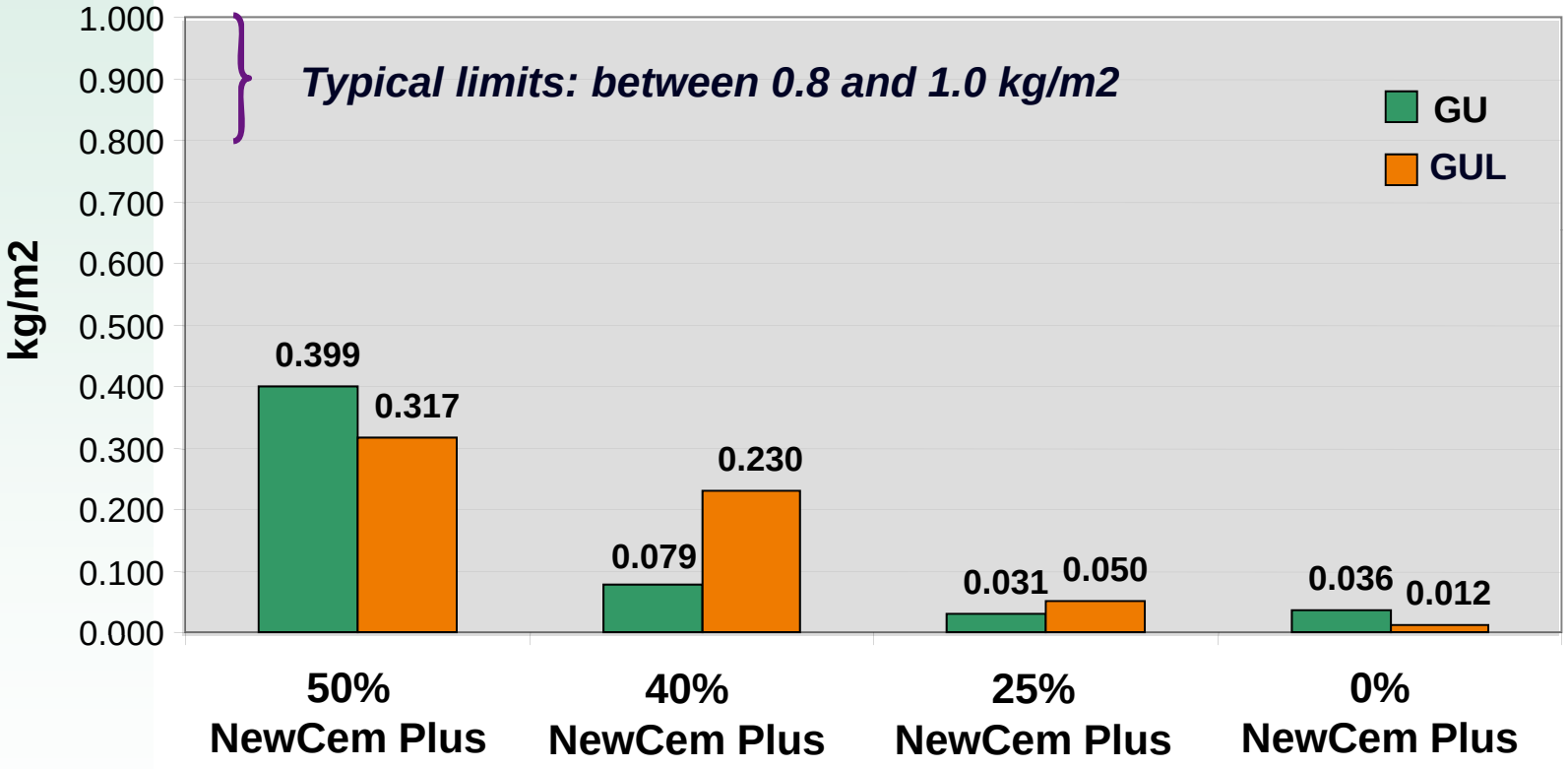
NewCem Plus
Optimized blend of slag and C ash

PLC Trial Pour – Core Strengths at 35 Days



Salt Scaling

Cumulative Weight Loss after 50 Cycles
ASTM C 672
Gatineau Trial



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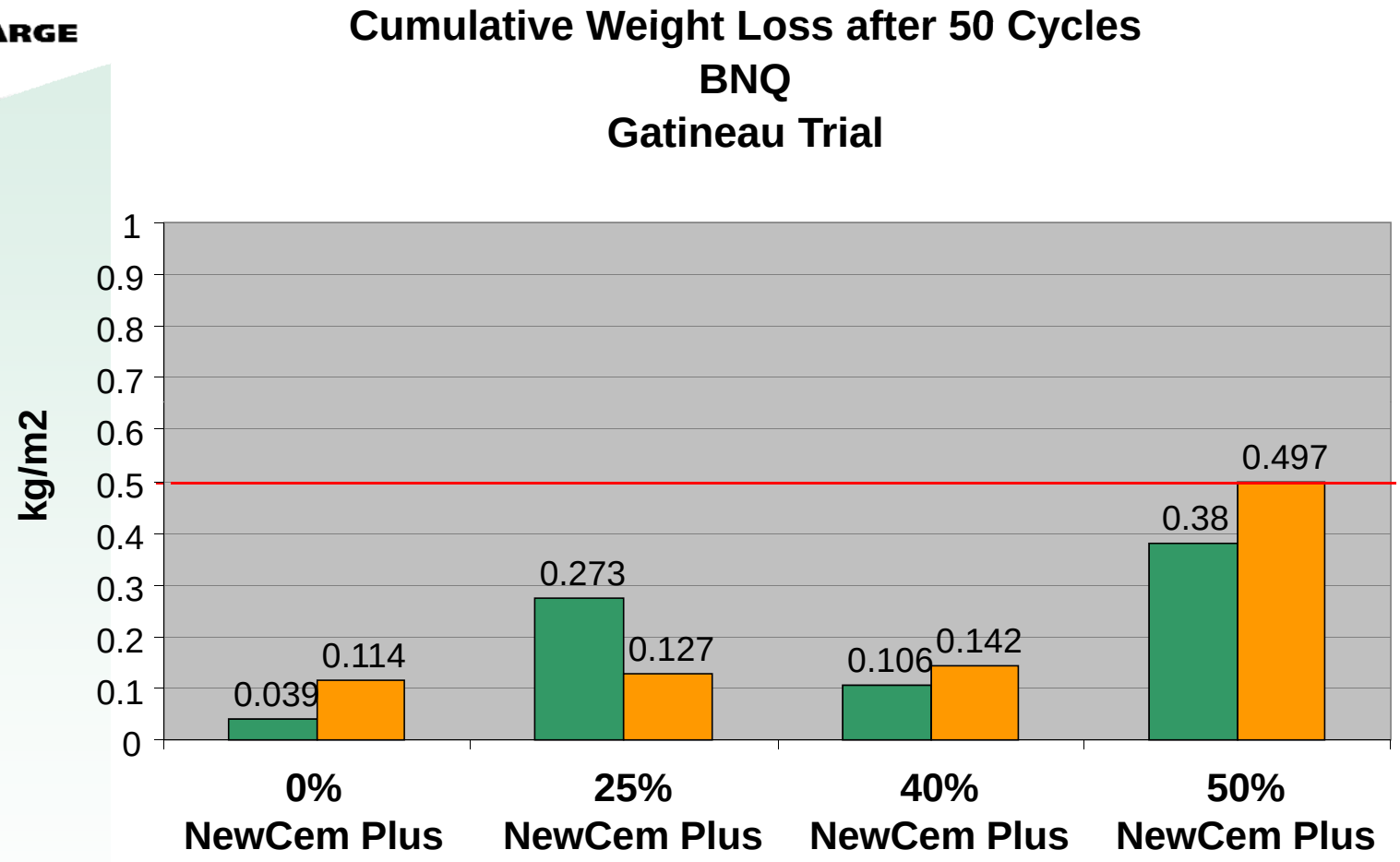
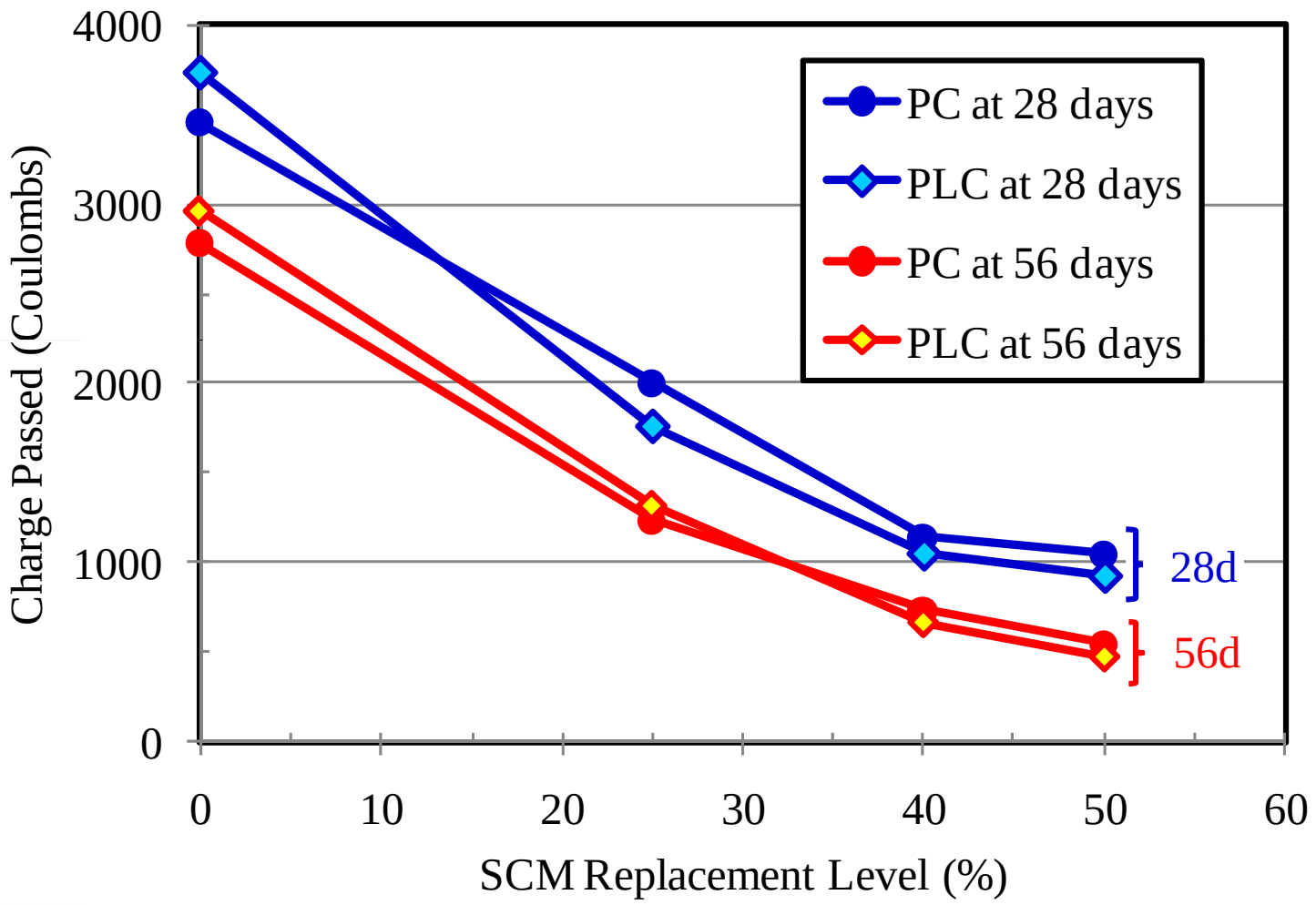
Optimized blend of slag and C ash

Salt Scaling

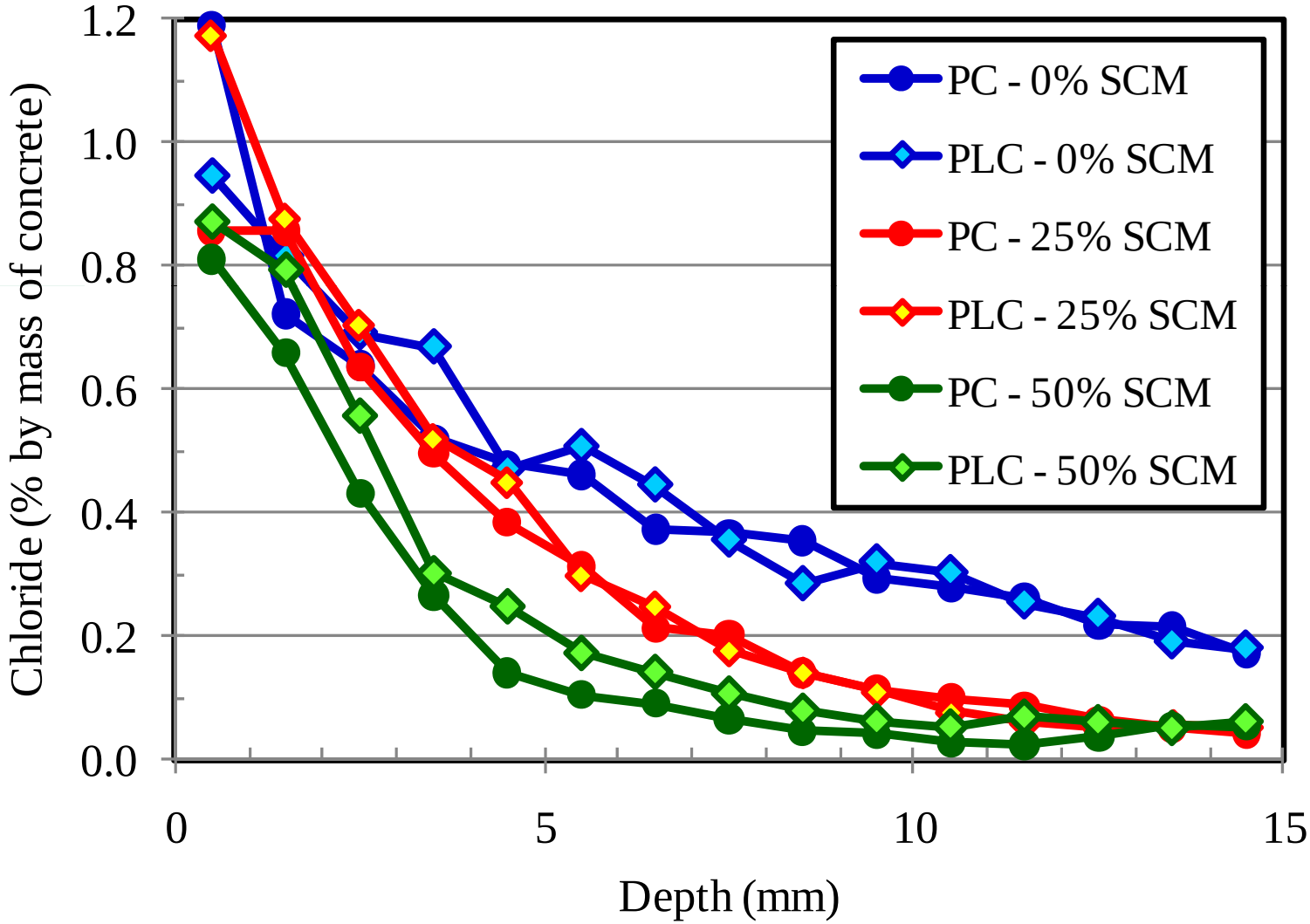


NewCem Plus
Optimized blend of slag and C ash

PLC Trial Pour – RCPT Results

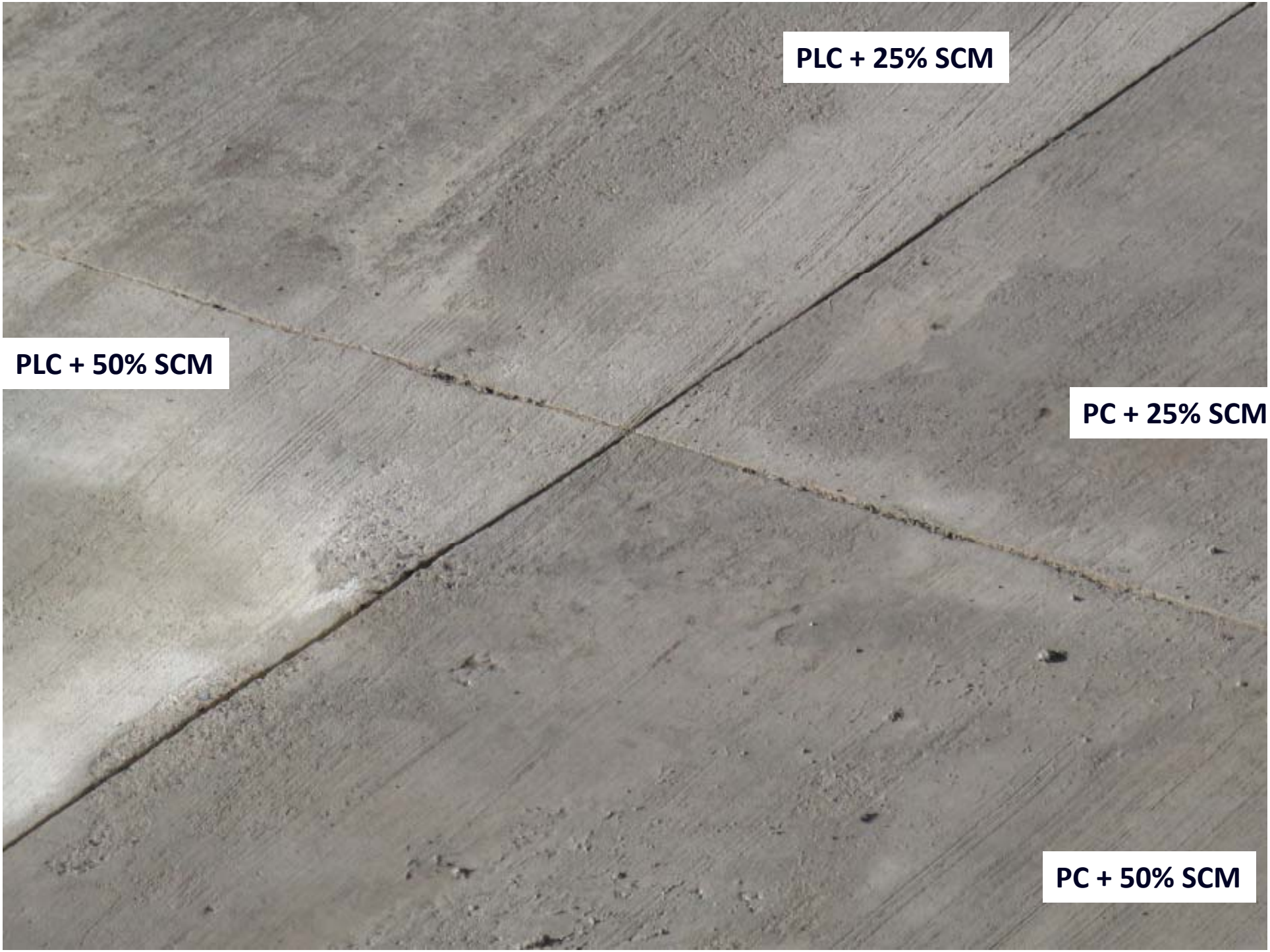


Chloride Profiles for Cores taken at 35 Days and Immersed in NaCl solution for 42 Days



PLC Trial Pour – C666 Test Results

SCM (%)	Cement Type	Air-Void Parameters		Durability Factor (%)
		Air (%)	L (μm)	
0	PC	5.3	173	101
	PLC	5.6	187	100
25	PC	4.9	148	101
	PLC	5.4	149	104
40	PC	5.6	164	101
	PLC	5.3	165	103
50	PC	5.6	150	102
	PLC	6.6	147	100


PLC + 25% SCM
PLC + 50% SCM
PC + 25% SCM
PC + 50% SCM

PLC Trial Pour – Conclusions

- No observable differences between plastic properties, placing and finishing of concrete with PC or PLC at a given level of SCM
- No significant difference between strength, permeability and chloride ion diffusion of concrete with PC or PLC at a given level of SCM
- Long-term strength, permeability and chloride ion resistance improved as level of SCM increased
- Resistance to salt scaling reduced as SCM level increased, especially at 50% SCM, however, outdoor panels as well as lab tests indicate acceptable performance
- No consistent trends in salt scaling resistance of PC concrete compared with PLC concrete at a given level of SCM

New Trials