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The Recovery and Pozzolanic Testing of Ponded and Landfilled Fly Ash

ADAA International Symposium

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Research Objectives

1. Assess the use of landfilled and ponded fly ash as pozzolan.
2. Evaluate the current methods for fly ash performance.
3. Develop new improved methods for fly ash performance.

Presentation summary

- Test Materials
  - Collection
  - Sieving
  - Air Classification
- Comparison of EN and ASTM Methodology
- Comparison of Landfilled to Current Production ash
- The Use of Resistivity for Pozzolanic Activity
  - At STP
  - Accelerated Method at 50 °C
- Summary and Conclusions

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Study Materials

Fly Ash Test Materials

- Landfilled harvested ash samples (LFA)
  - Closed Midwest (Ohio) power plant (LFA-1 also LFA-200, LFA-325, LFA-500)
  - Low Sulfur Compliance Bituminous Coal
  - Commercial Harvested Ash LF-2

- Marketed Current Production Ash (CPA) operating power plants in:
  - Ohio CPA-1 (CPA-1 also CPA-200, CPA-325, CPA-500)
  - Alabama CPA-2
  - Illinois CPA-3
  - New Mexico CPA-4
  - North Dakota CPA-5 (C/F)

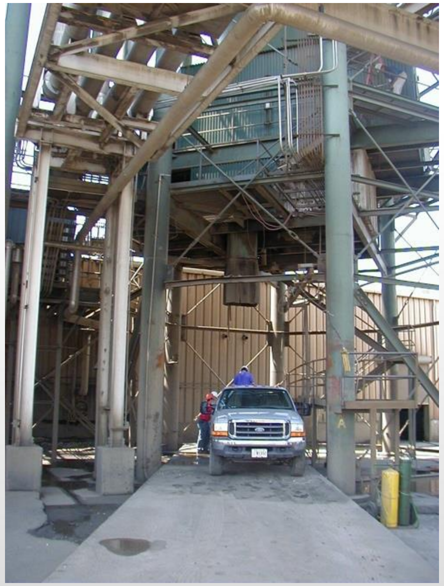
Test Materials: Auger Samples

- Auger Samples
  - Closed Southeastern power plant
  - Bagged Auger Samples from filled slurry pond

Name	Interval (feet) from	to	Wt. Dry g
AG-1	21.25	24	190.3
AG-2	25	28	166.9
AG-3	32	36	150.5
AG-4	40	44	171.6
AG-5	48	52	133.4
AG-6	56	59	158.2

Fly Ash Collection 2023/2024

Major Elements



Plant	A	B	C	D	E	F	Ave A-F
SiO_2	44.93	35.94	43.56	45.31	44.32	45.99	**43.34**
Al_2O_3	21.63	16.09	19.02	18.77	17.02	17.18	**18.29**
Fe_2O_3	19.00	30.38	15.08	15.23	14.89	19.49	**19.01**
CaO	**3.76**	**10.49**	**10.50**	**8.06**	**11.25**	**4.98**	**8.17**
MgO	0.75	0.75	1.03	1.13	1.31	0.99	**0.99**
Na_2O	0.51	0.29	0.84	0.69	0.94	0.76	**0.67**
K_2O	2.16	1.58	1.78	2.43	1.90	2.13	**2.00**
P_2O_5	0.23	0.07	0.20	0.17	0.15	0.10	**0.15**
TiO_2	1.08	0.64	0.96	0.97	0.95	0.96	**0.93**
SO_3	1.56	0.74	2.34	3.67	2.67	2.58	**2.26**
LOI	1.77	2.88	5.54	3.38	2.03	1.43	**2.83**

*ASTM Limit=5% (SO_3)

*ASTM Limit=6% (LOI)

*C-618

Additional Test Materials

Pozzolans

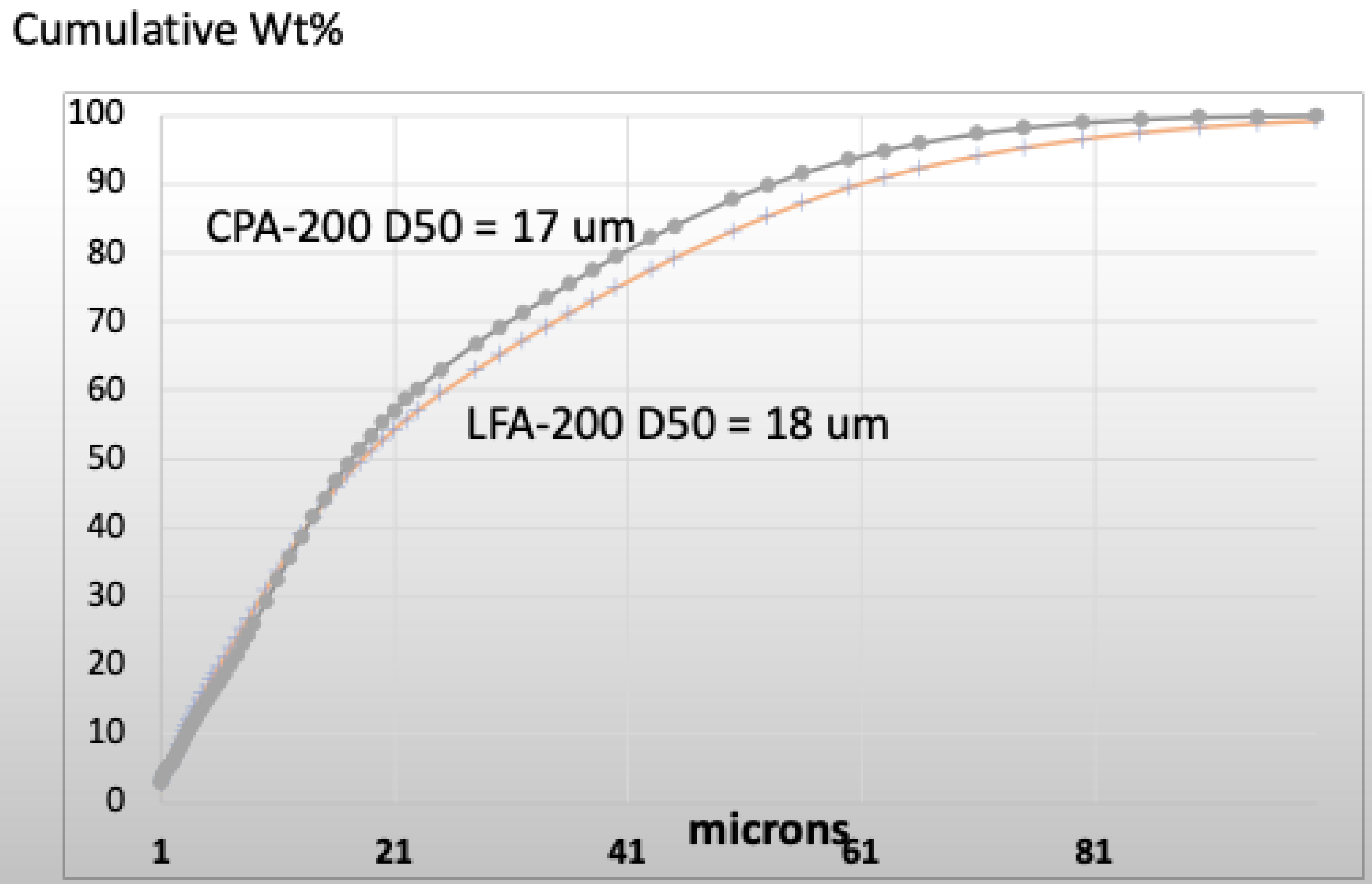
- Eco Materials Micron-3 Class F (MIC-3)
- Milled Pumice Class N (CN)

Non Pozzolans

- Milled Ohio River Sand (ORBS)
- Limestone (Lim-3, Lim-17)

ORBS

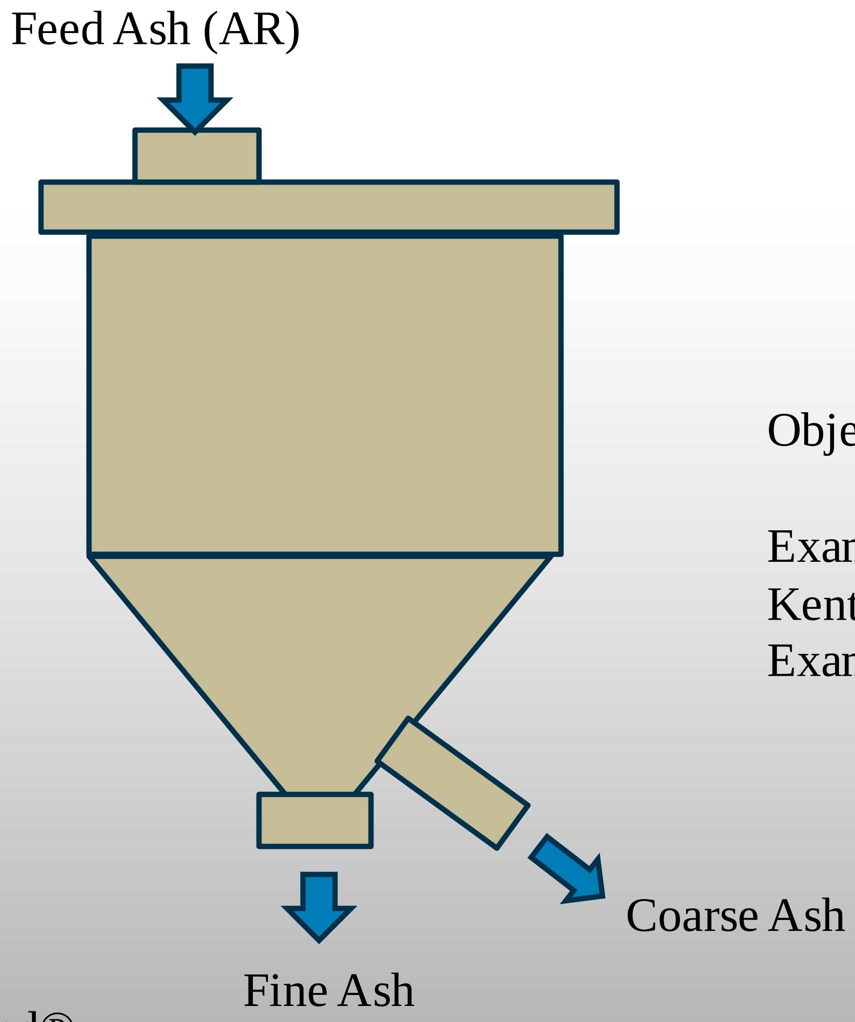
Sieving of Landfilled and Current Production Ash.



Objectives:
Keep comparison on common basis
Examine effects of improved fineness

Air Classification

20-inch diameter, 1 tph Sturtevant Whirlwind®



Objectives:

Examine commercial technology on Kentucky power plant fly ash

Examine products of classification

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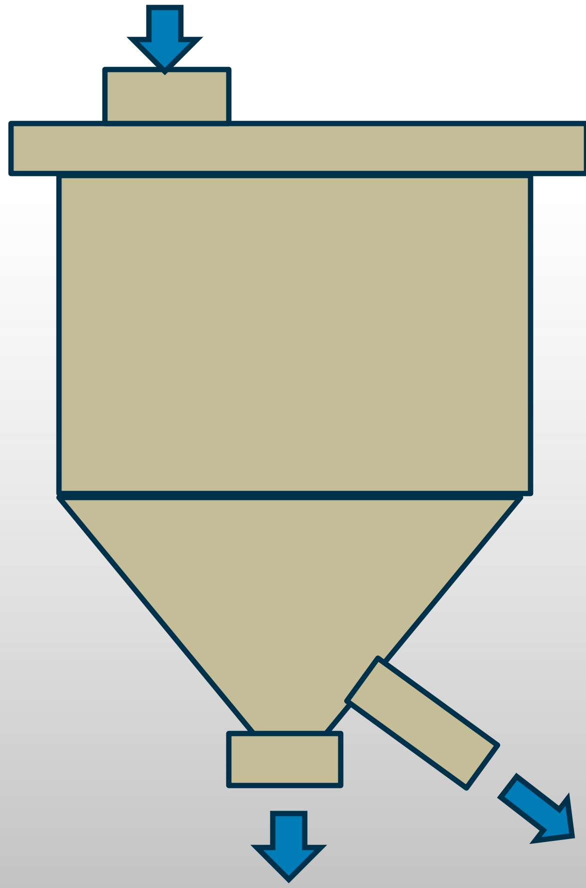
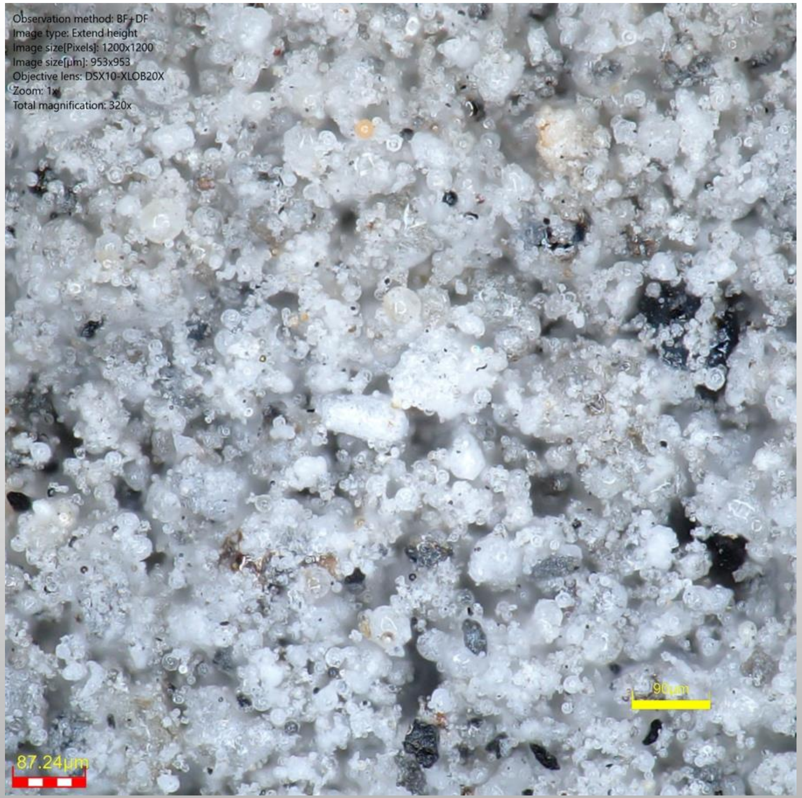
Air Classification Coarse and Fine Examples (size)



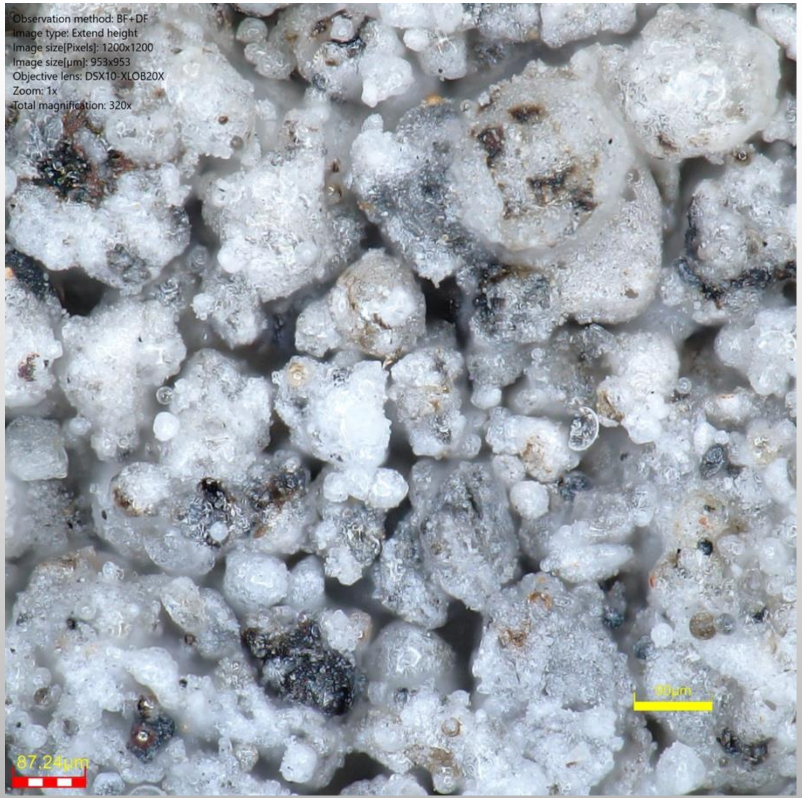
Air classification is most effective on coarse ash

Air Classification Plant SM Coarse Ash

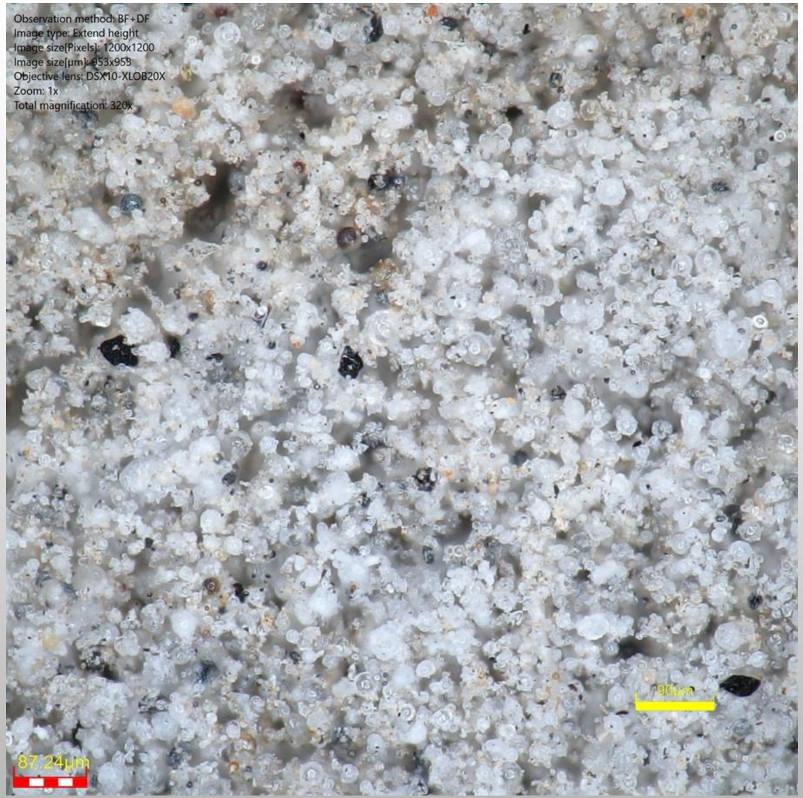
As Received



Coarse



Fines



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ASTM C 618 and EN 450 S.I.

ASTM C618, *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*

BS EN 450-1:2012 - *Fly ash for concrete. Definition, specifications and conformity criteria*

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Comparison of ASTM C 618 and EN 450 S.I. Specifications

Parameter	ASTM C 311	EN 196
Water	Variable, Adjusted to Flow	Fixed
Ash Substitution Rate	20%	25%
Media	2-inch (50mm) cubes	40 x 40 x 160 mm prism
Sand	ASTM C 778	EN-196-1
Test Criteria	75% of Control @ 7 or 28 days	75% of Control @ 28 days and 85% of Control @ 90 days

Comparison of Sand

Void Volume = 43% loose; 36% tapped

Void Volume = 36% loose; 28% tapped

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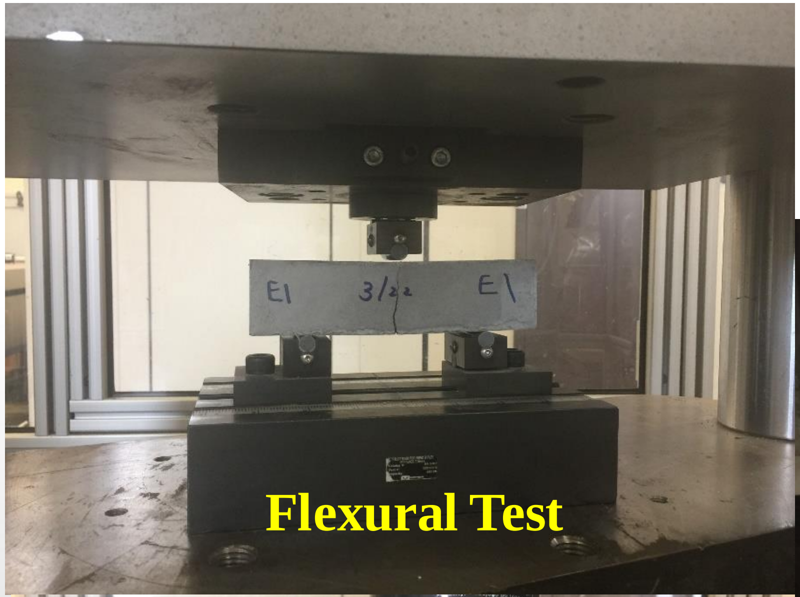
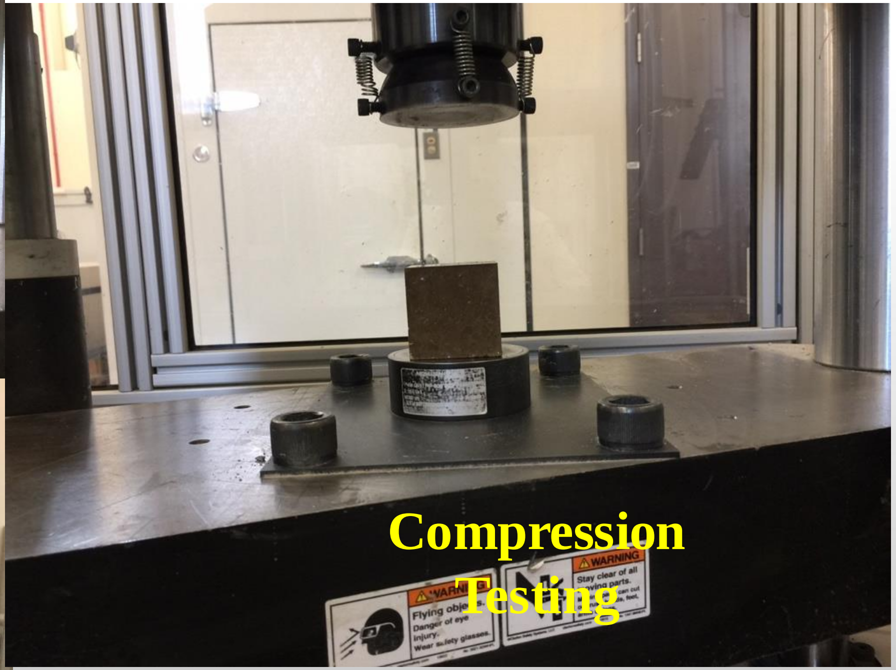
Specimen Molding

EN 196 and ASTM C109 Testing





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Results ASTM C 618 vs EN 450 S.I.

- ASTM S.I. is not selective for pozzolanic materials (false positives, e.g. ORBS, Lim-17, Lim-3, nothing).
- EN is selective for pozzolanic materials (false negatives).
- Why does ASTM Fail?
  - Sand
  - Method
  - Substitution Rate
  - Time Interval of Tests

		S.I. % of Control		
		ASTM	EN	EN
Test		7 day	28 day	90 day
1	Control			
1	CPA1 <200	87%	83%	98%
2	Control			
2	ORBS	**81%**	**77%**	**75%**
2	LIM-17	**91%**	**77%**	**77%**
2	LA1 <200	88%	90%	98%
3	Control			
3	LA1 <200	87%	103%	117%

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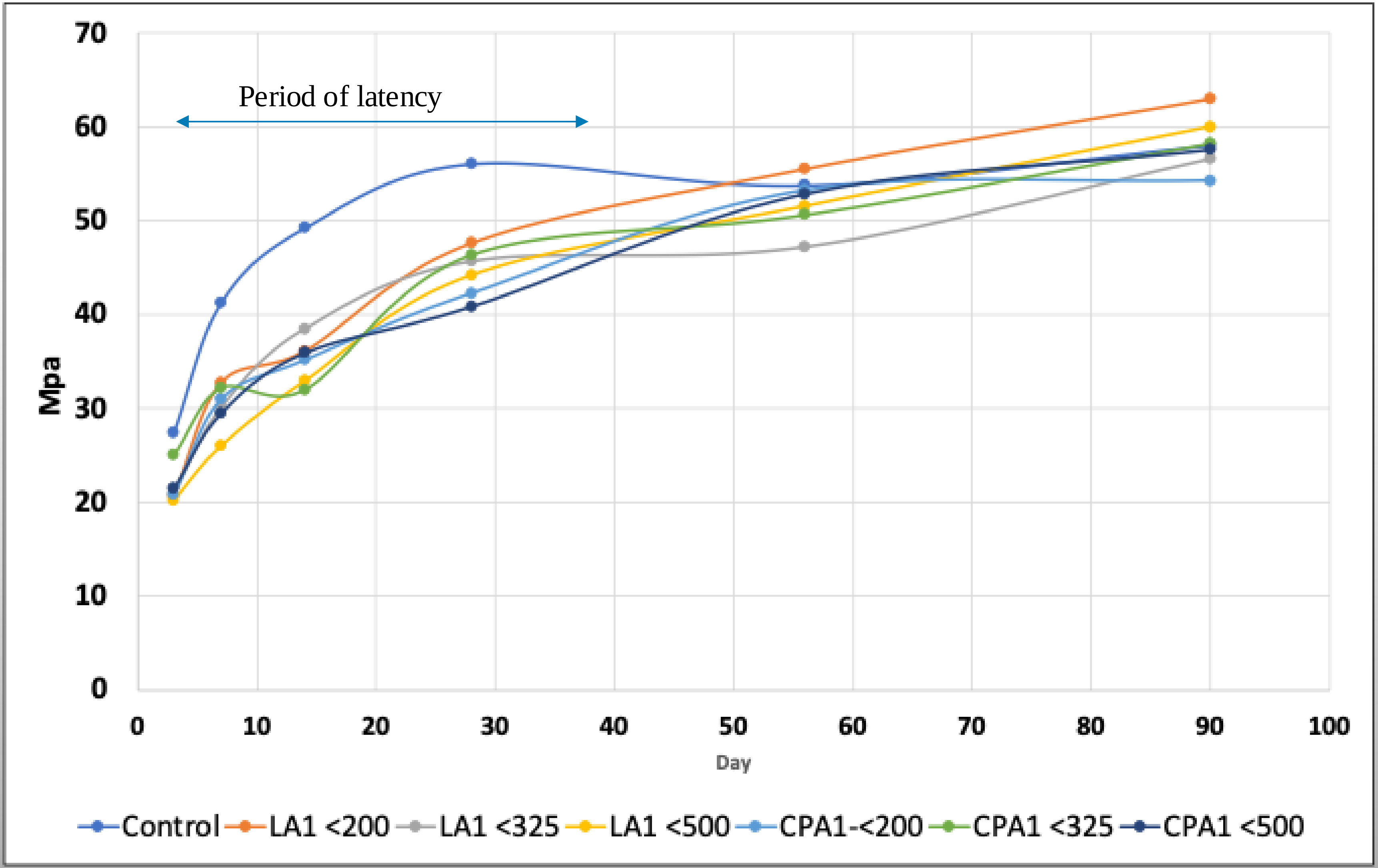
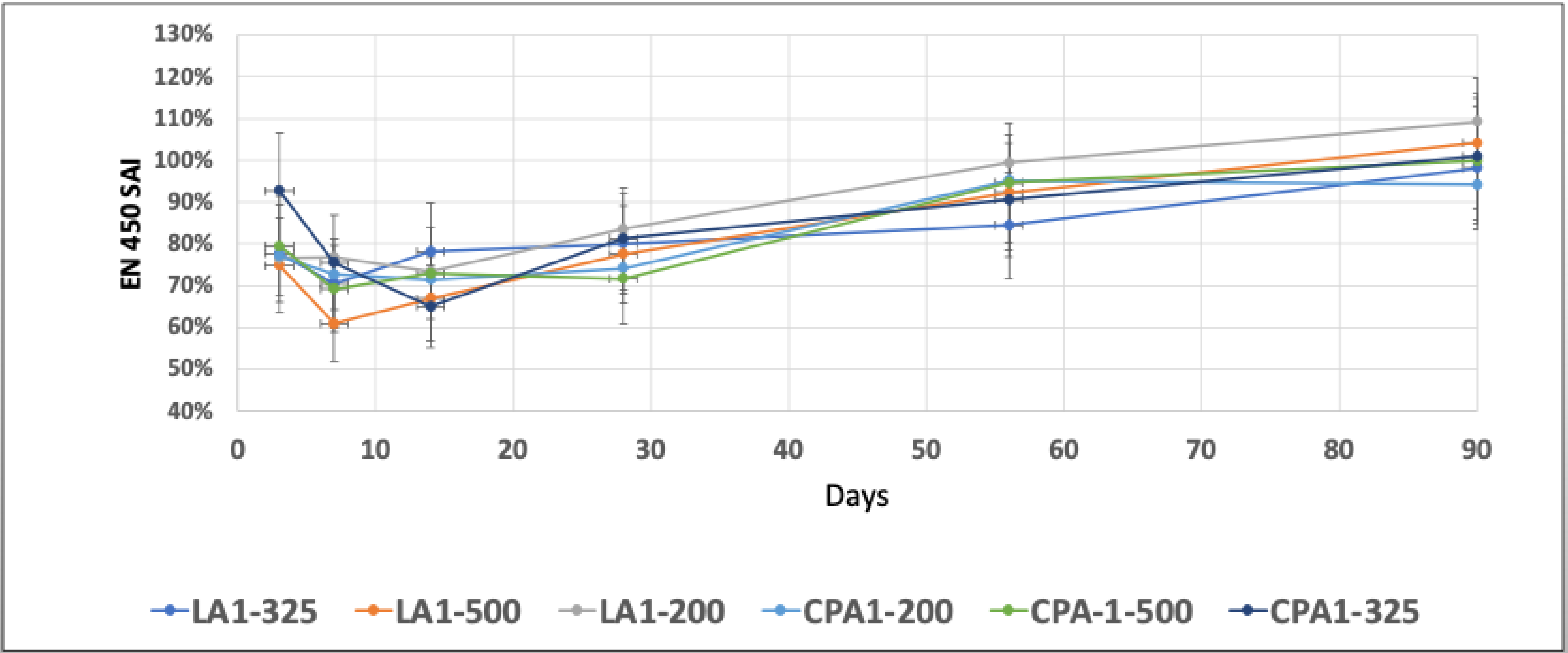
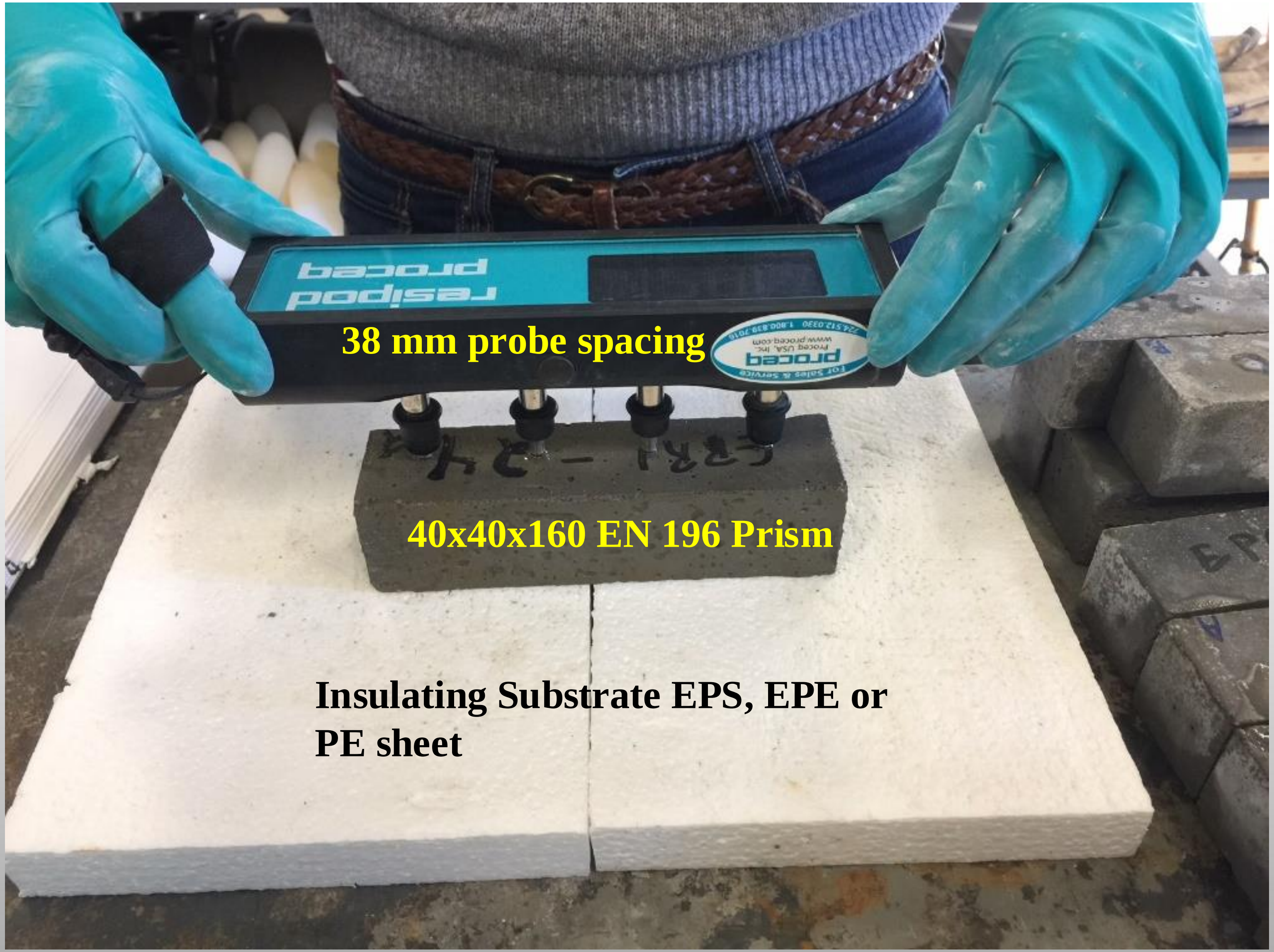
EN 196 Compressive Strength for land filled and fresh ash.



EN 450 S.I. With Error Bars (2s)



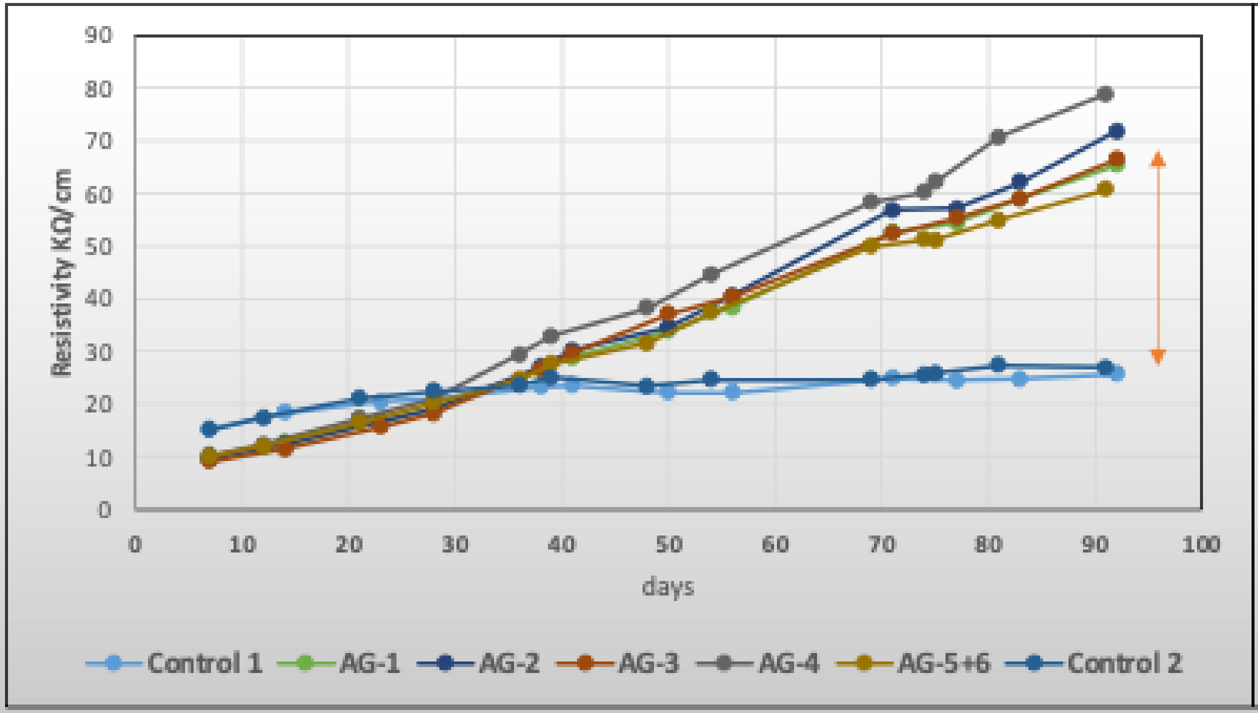
Resistivity Measurements

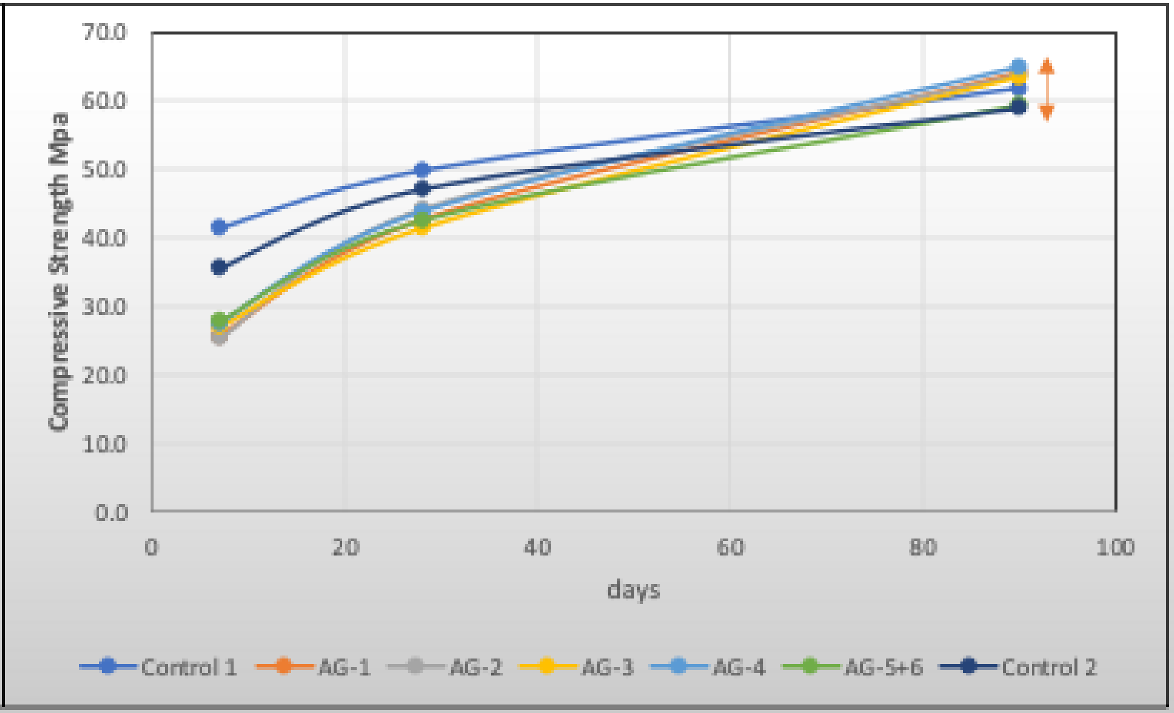


Resistivity Measurements

- Protocols
- Stored in misting room at 25 °C
- Six prisms at a time
- Prisms measured in saturated surface dry condition
  - pat dry with towels, do not dry out
- Rotate and measure each side and average
- Use nonconductive surface

Selectivity: Resistivity versus Compressive Strength for auger samples from pond





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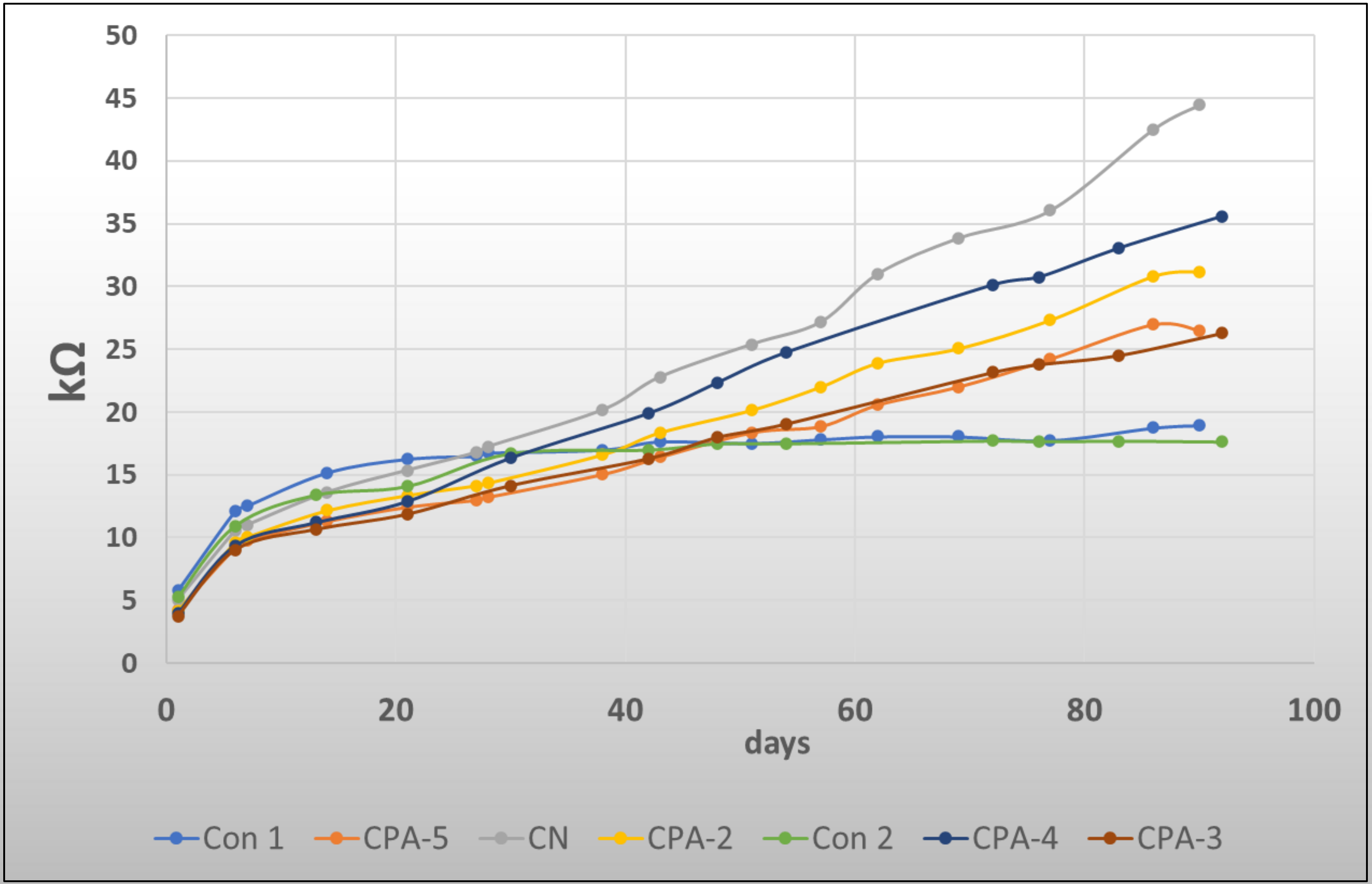
Resistivity @25ºC for Commercial Class F Ashes

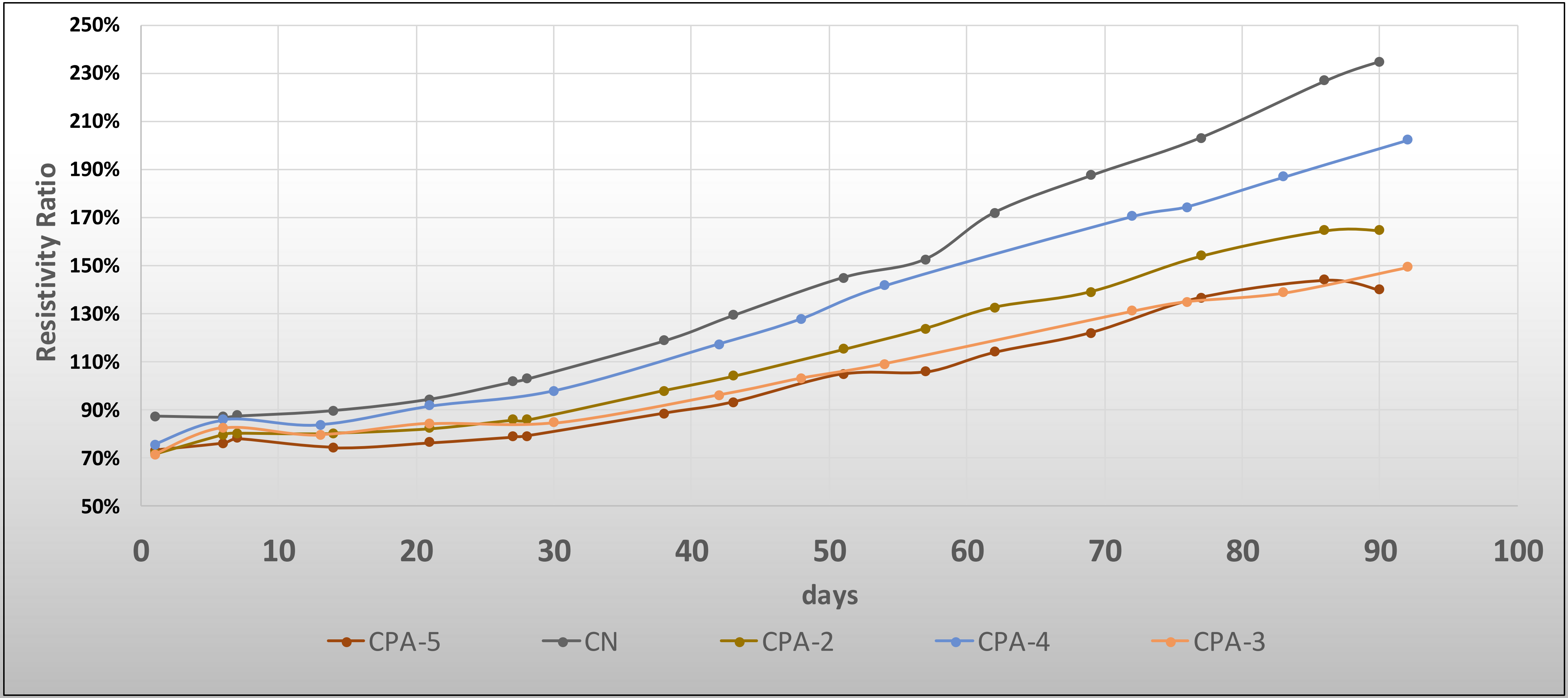


Milled Pumice

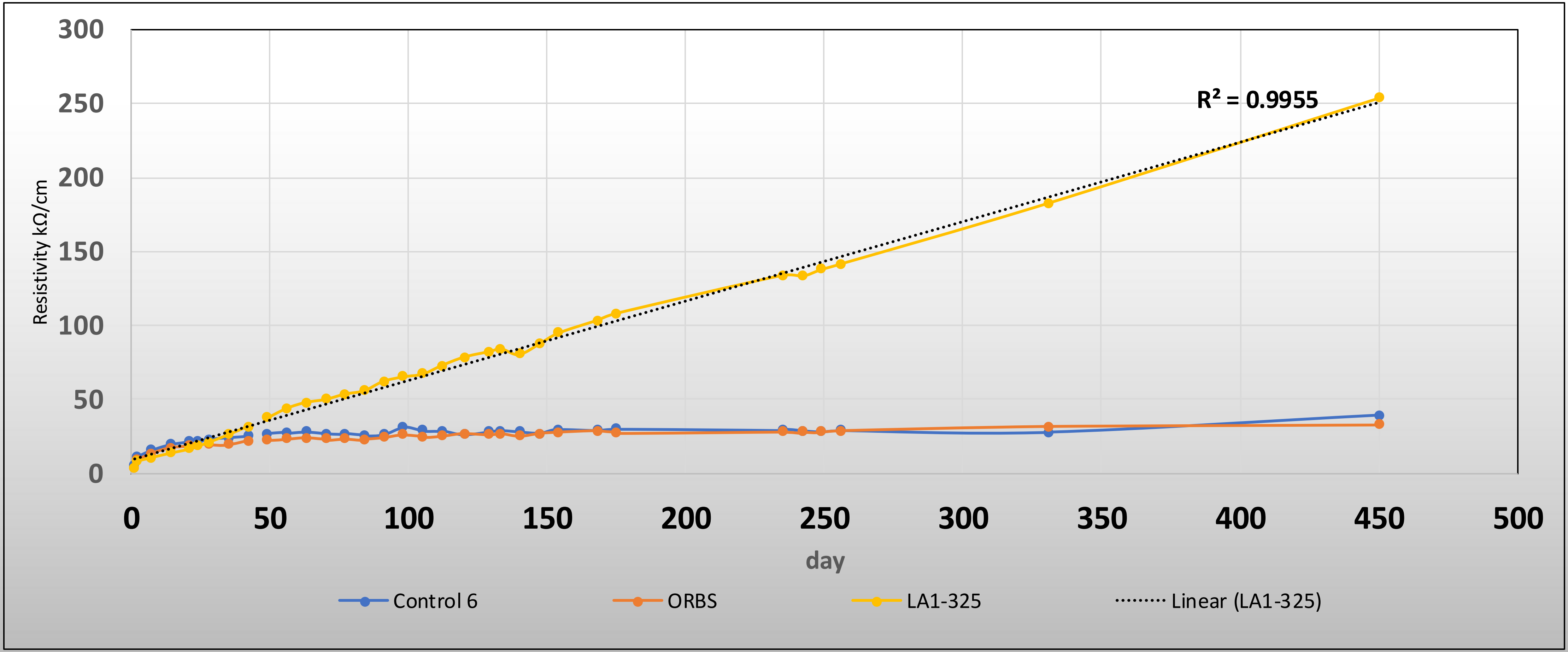
Class F fly ash

Controls

Resistivity Ratio for Class F fly ash



Resistivity over 1.2 years



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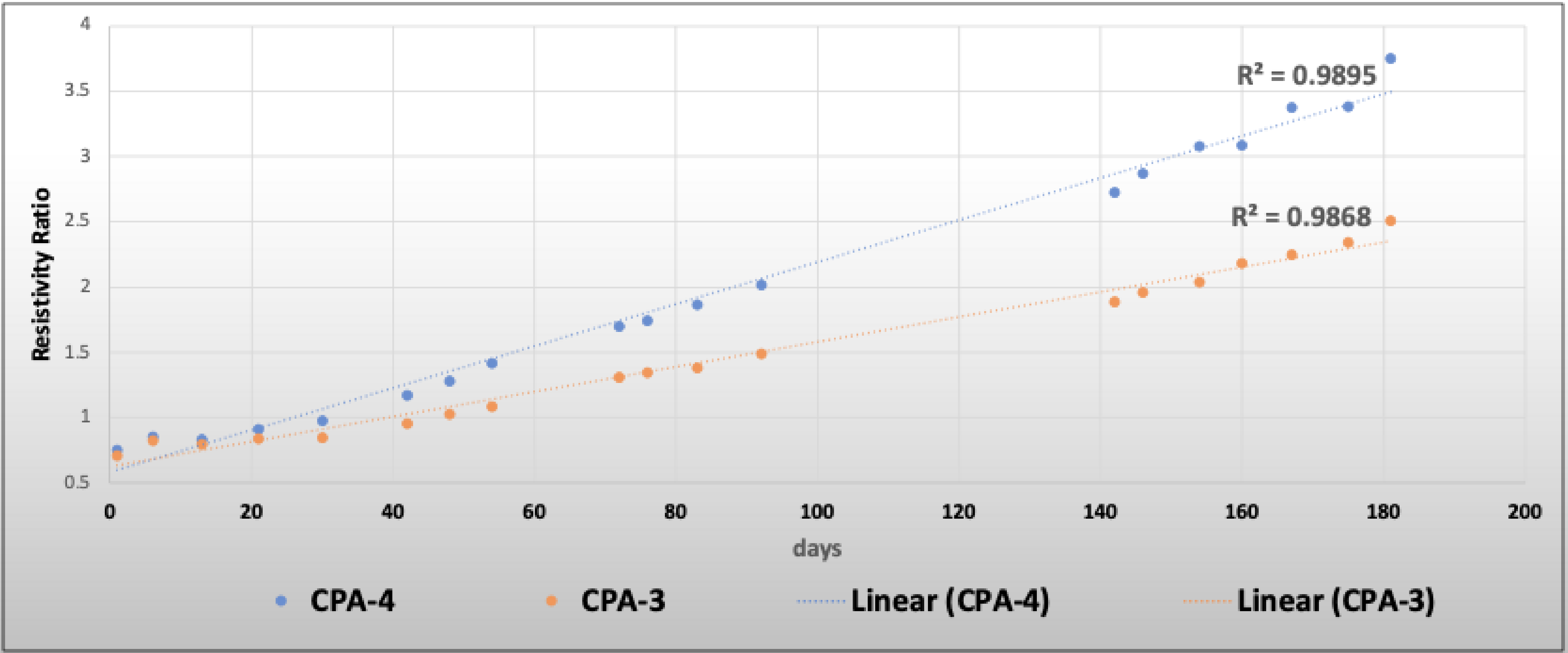
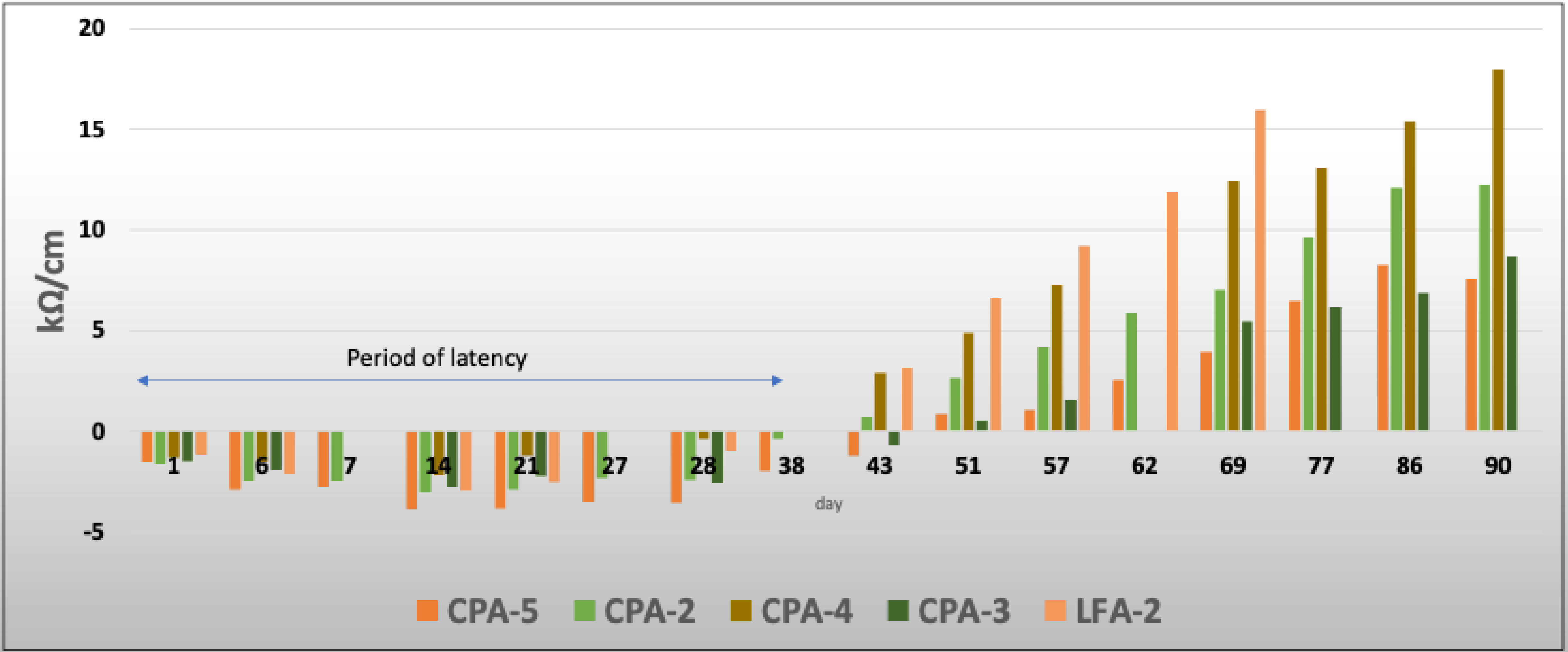
Resistivity Ratio Over 1/2 year



Difference in Resistivity between Control and Fly Ashes @25°C



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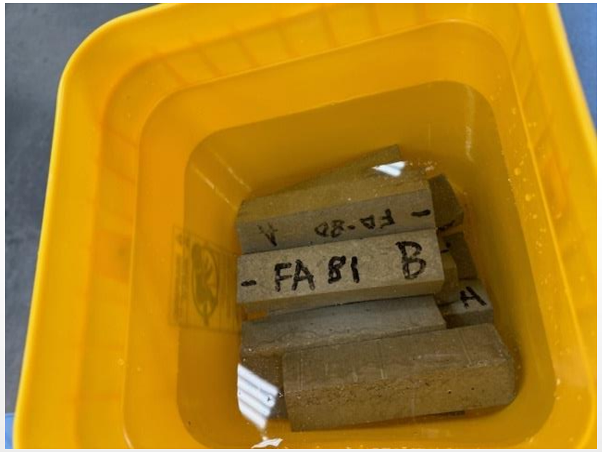
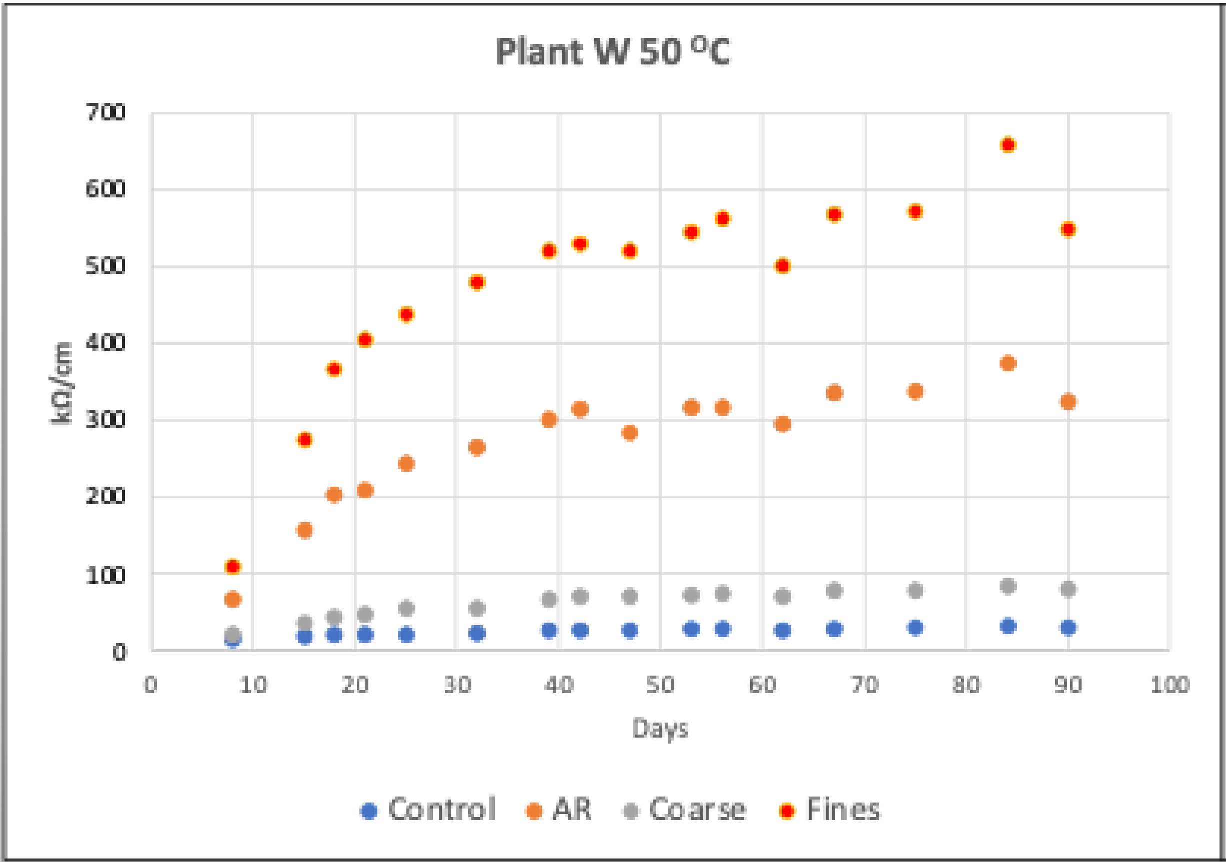
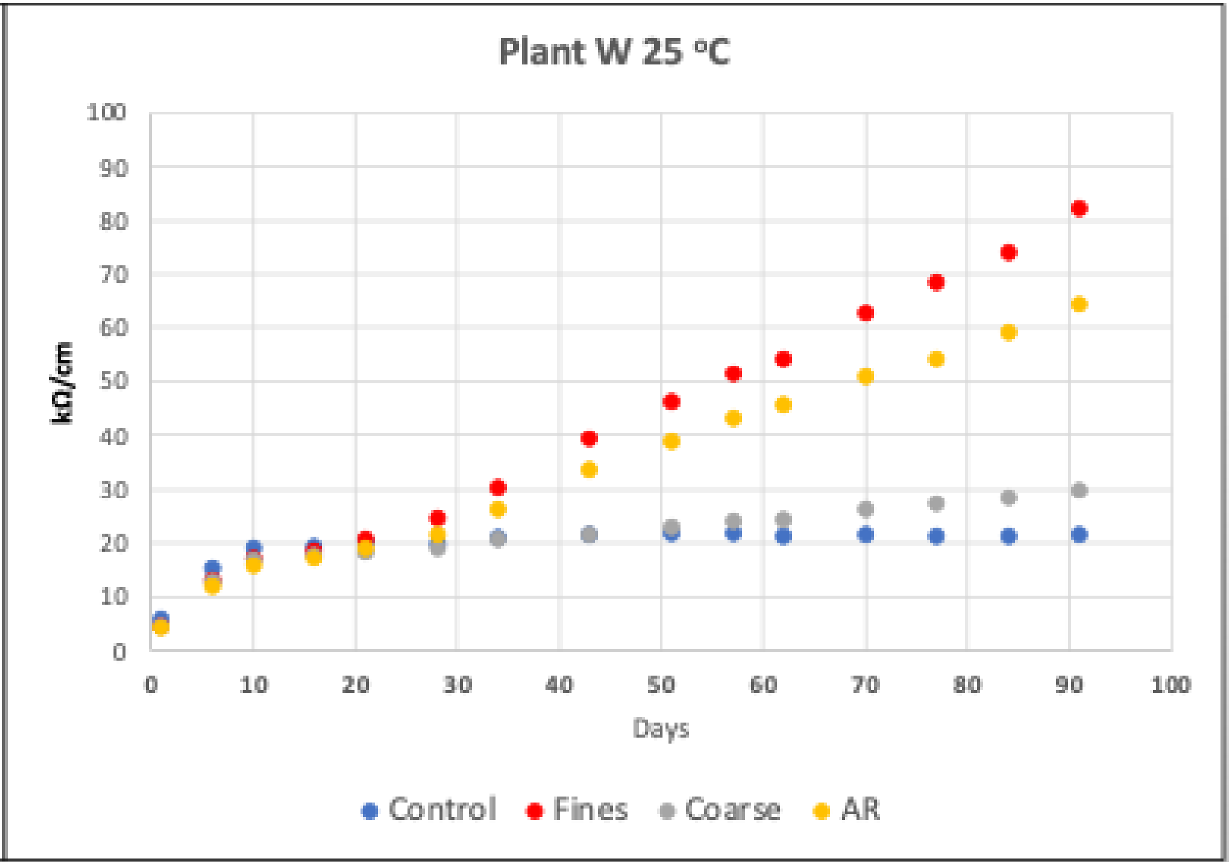
Accelerated Testing at 50 °C: Protocols



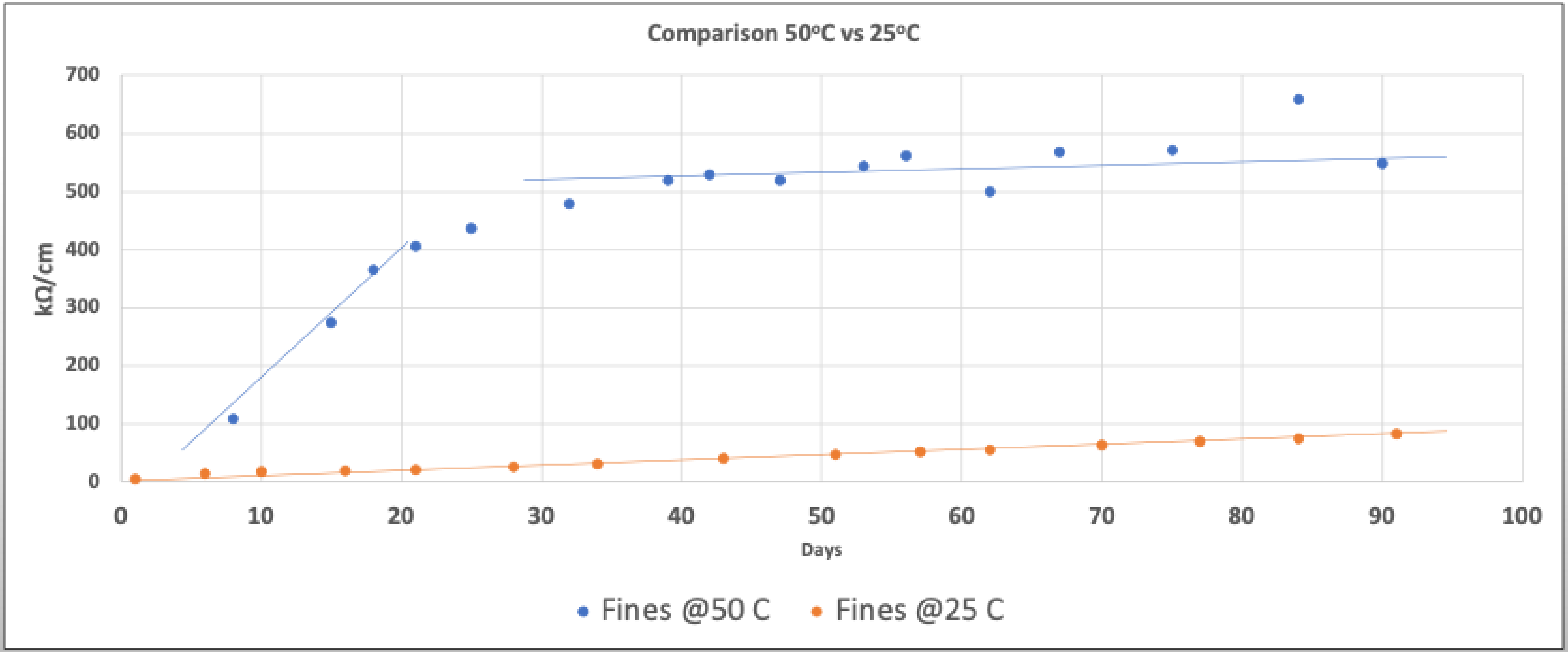
- **Stored in curing chamber at 50 °C**
- **Cooled to room temperature under water**
- **Six prims at a time**
- **Prisms measured in saturated surface dry condition**
  - **pat dry with towels, do not dry out**

Comparison of Classified ash at 25 and 50 °C from Plant W

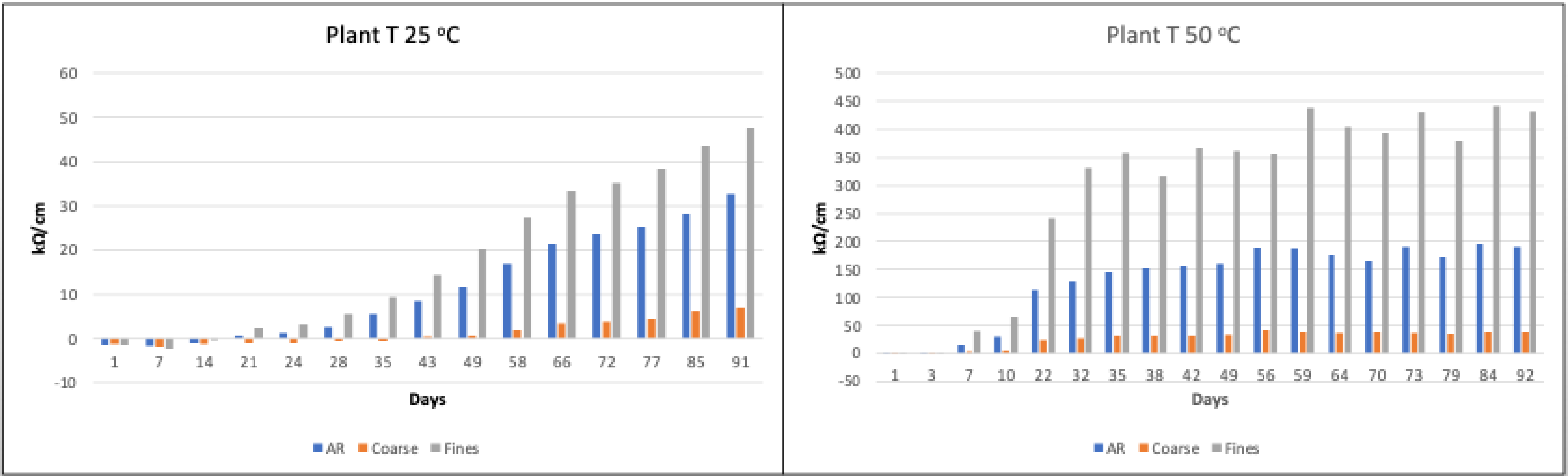




Comparison of Fines at 25 and 50 °C at Same Scale



Difference in kΩ between control and fly ash @25 and 50^oC



Air Classified Coarse Fly Ash from Plant SM @50ºc 7days

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Conclusions and Observations

- Strength Activity Index as specified in ASTM C618 does not measure pozzolanic activity, but rather the physical effects relatable to packing and rheology.
- EN 450 based strength index tests provide a better, but still flawed, measure of pozzolanic activity.
- Harvested Class F will perform on par with, or outperform, current production ash, if it meets fineness and LOI specifications.
- Increasing the fineness of the class F ash by scalping at 200, 325 and 500 mesh (over the range from 75 to 25 μm) did not improve the performance in any of the pozzolan tests.
- Wenner probe resistivity is a rapid, simple, precise, and non-destructive when paired with 40x40x160 mm (EN 196) prisms.
- The pozzolanic reactivity of Class F fly ash cured @25^{o}C was found to be slow with a substantial latency period of 28 days or more.
- Increasing the curing temperature of Class F fly ash to 50 ^{o}C greatly increased the rate of reaction, decreasing the latency period and enhancing selectivity. The data suggests that a reliable 7-day test may be feasible.

Thanks!

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