

NESMEA 2009

Resistivity of Water Saturated Concrete as an Electrical Indicator of its Chloride Penetration Resistance

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Presentation Objectives

- Describe the Rapid Chloride Permeability Test (ASTM C1202)
- Describe the Surface Resistivity Test (FM 5-578 SR)
- Relationship Between RCP and SR.
- Describe the Bulk Diffusion Test.
- Relationship Between SR and BD.
- SR Behavior of Select Mixes
- Conclusions

The RCP Test

Cut
1st Day of Test
26th Curing Day



Epoxy Slice
1st Day of Test
26th Curing Day



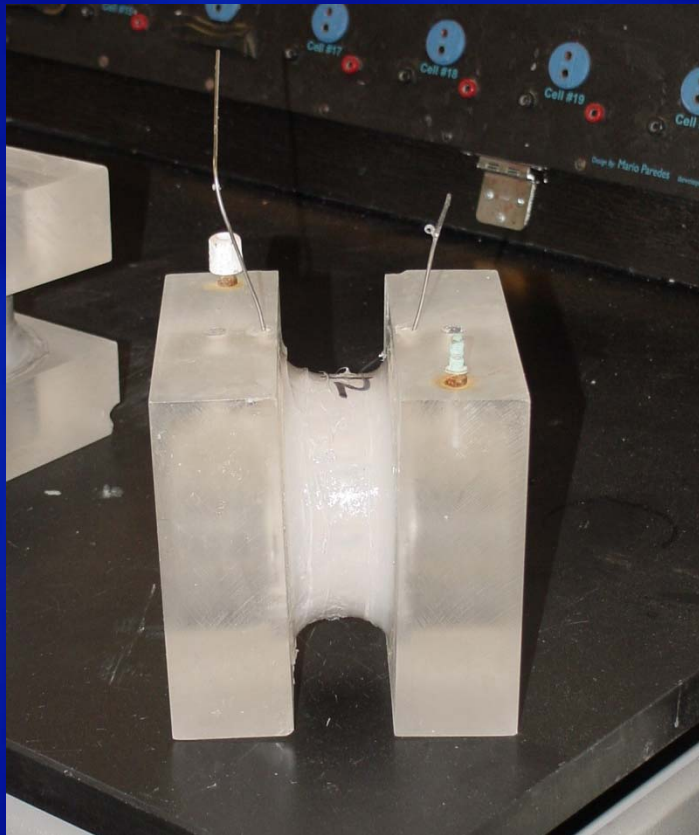
The RCP Test

Desiccate
2nd Day of Test
27th Curing Day

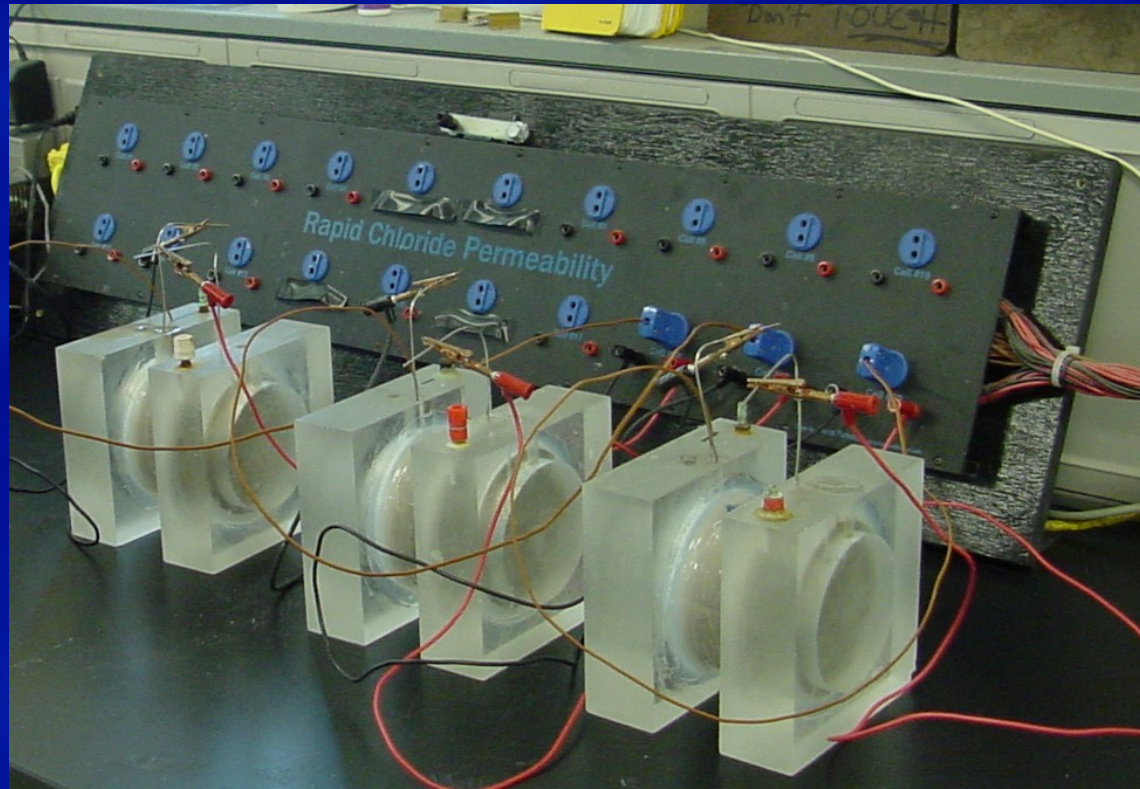


The RCP Test

Cell Formation
3rd Day of Test
28th Curing Day



Perform Test
3rd Day of Test
28th Curing Day

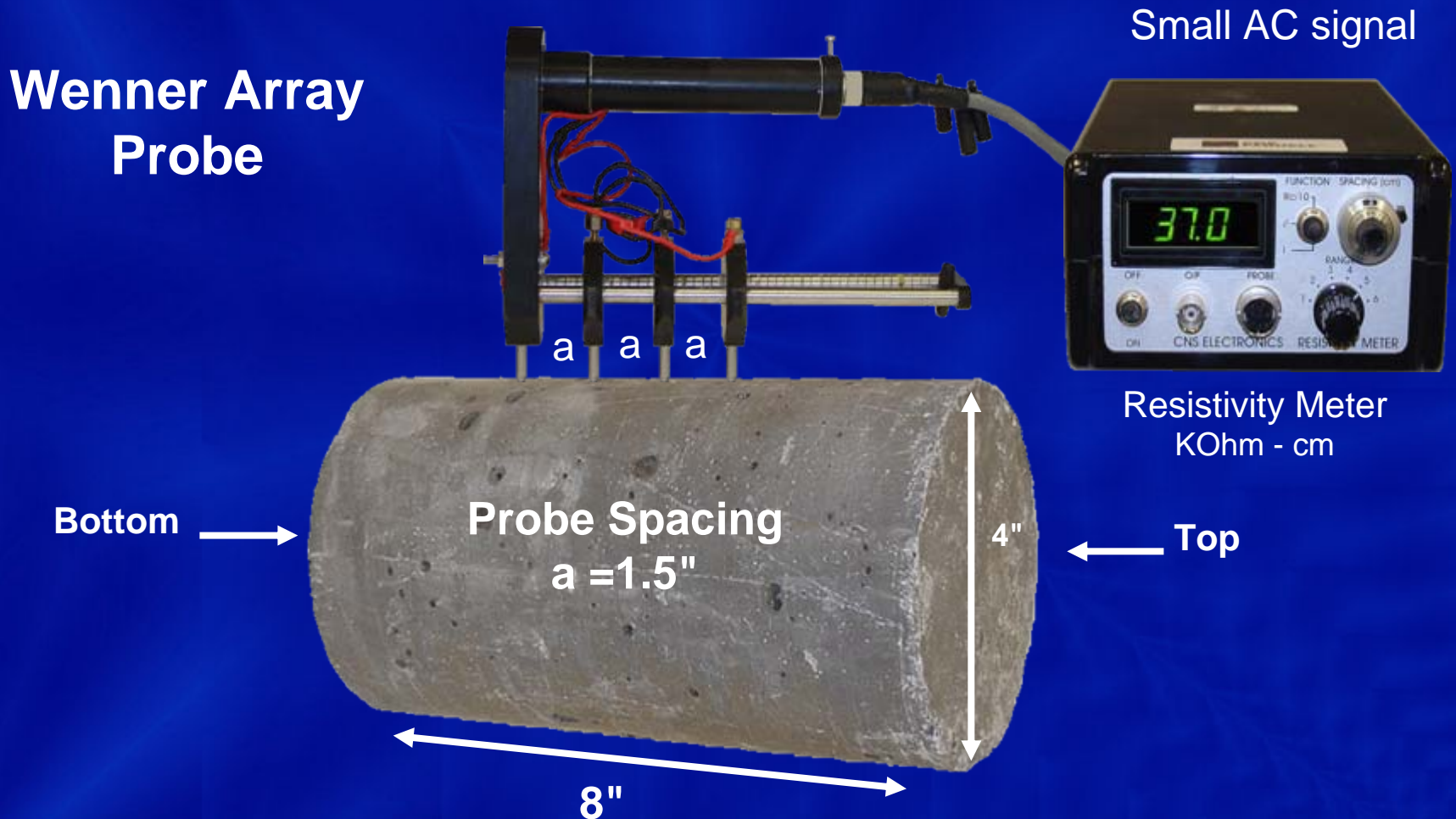


Surface Resistivity Test

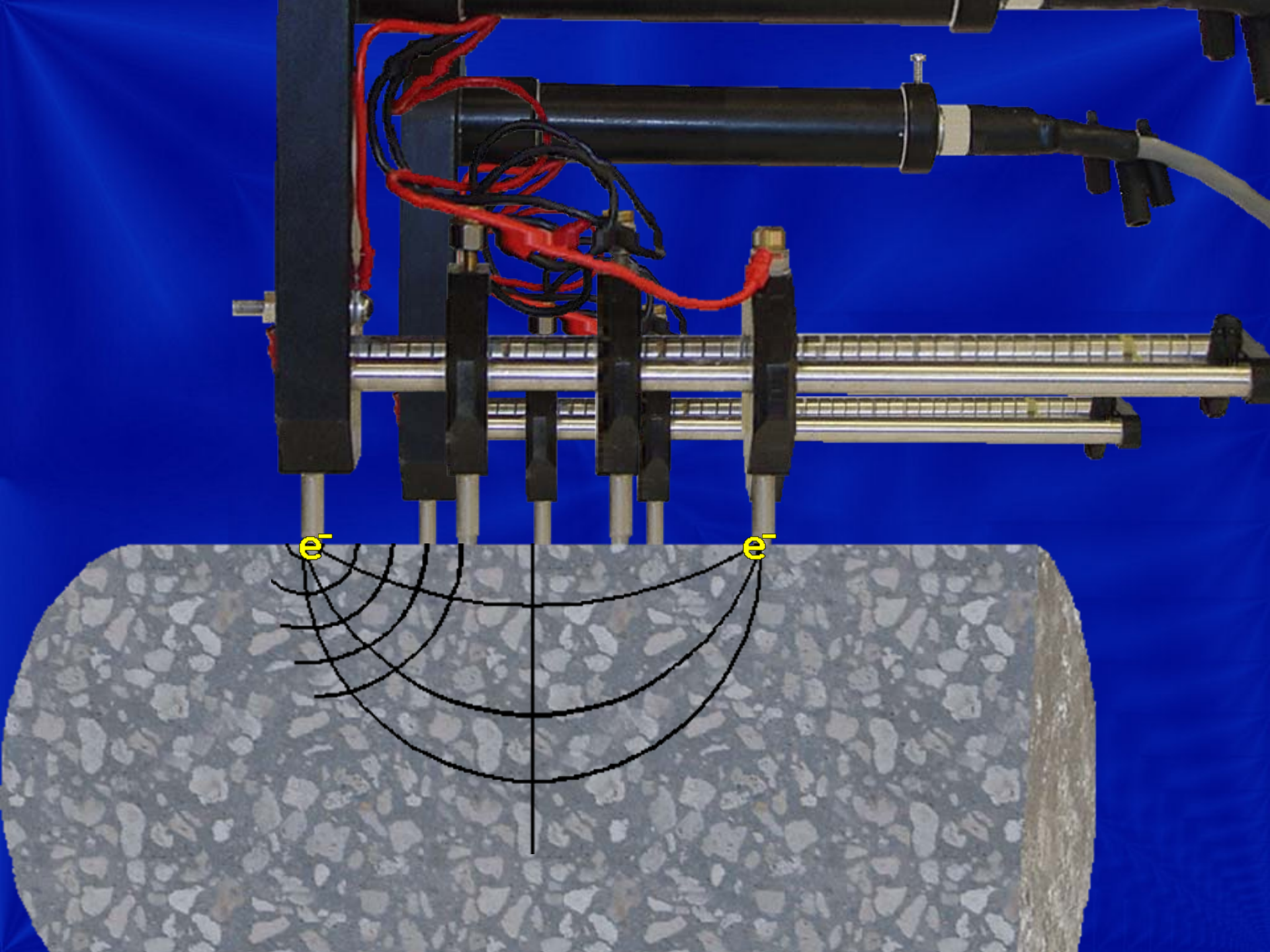
FM 5-578



Surface Resistivity Test

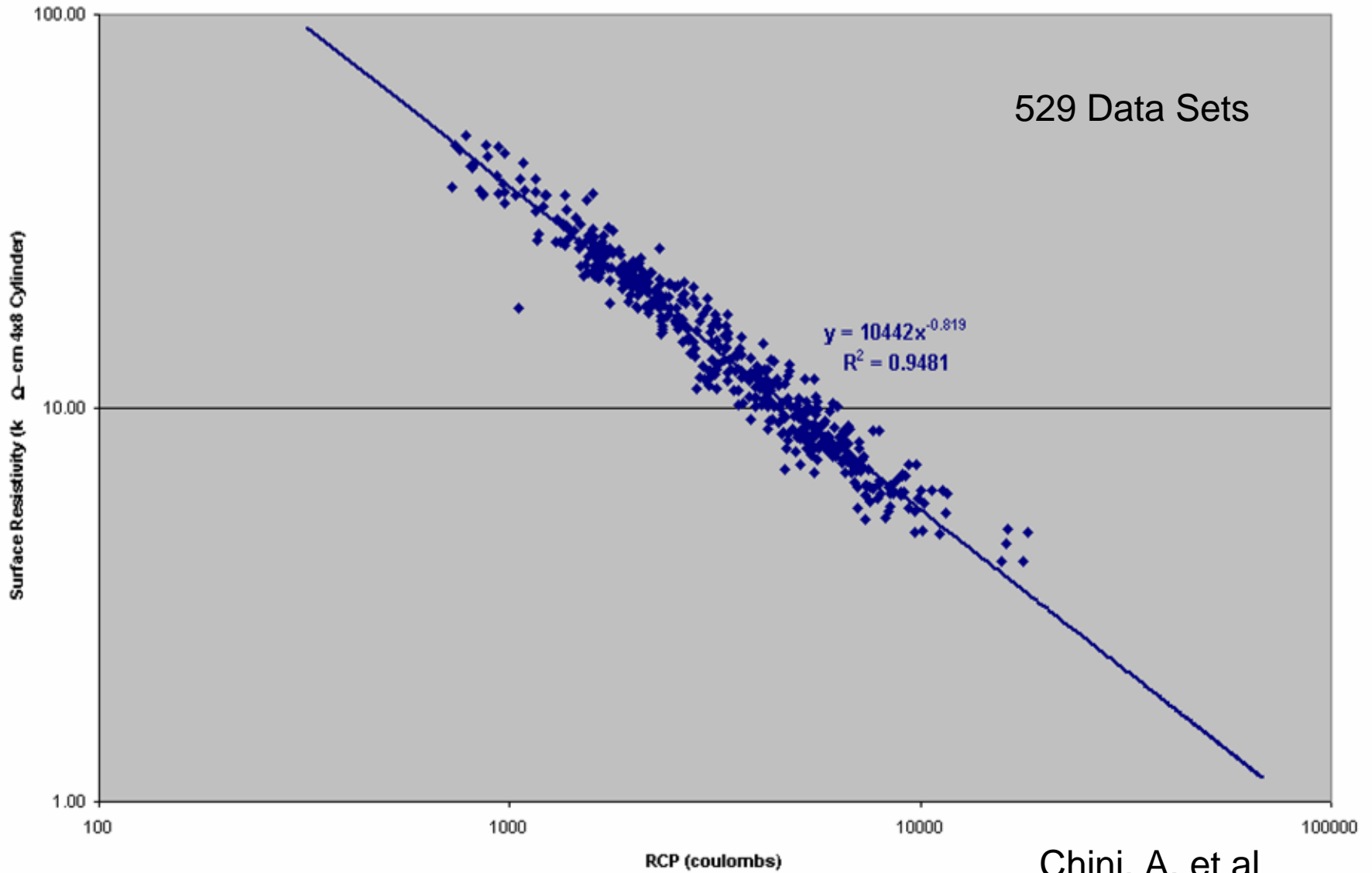


- Test measures the resistivity of the void system full of water.



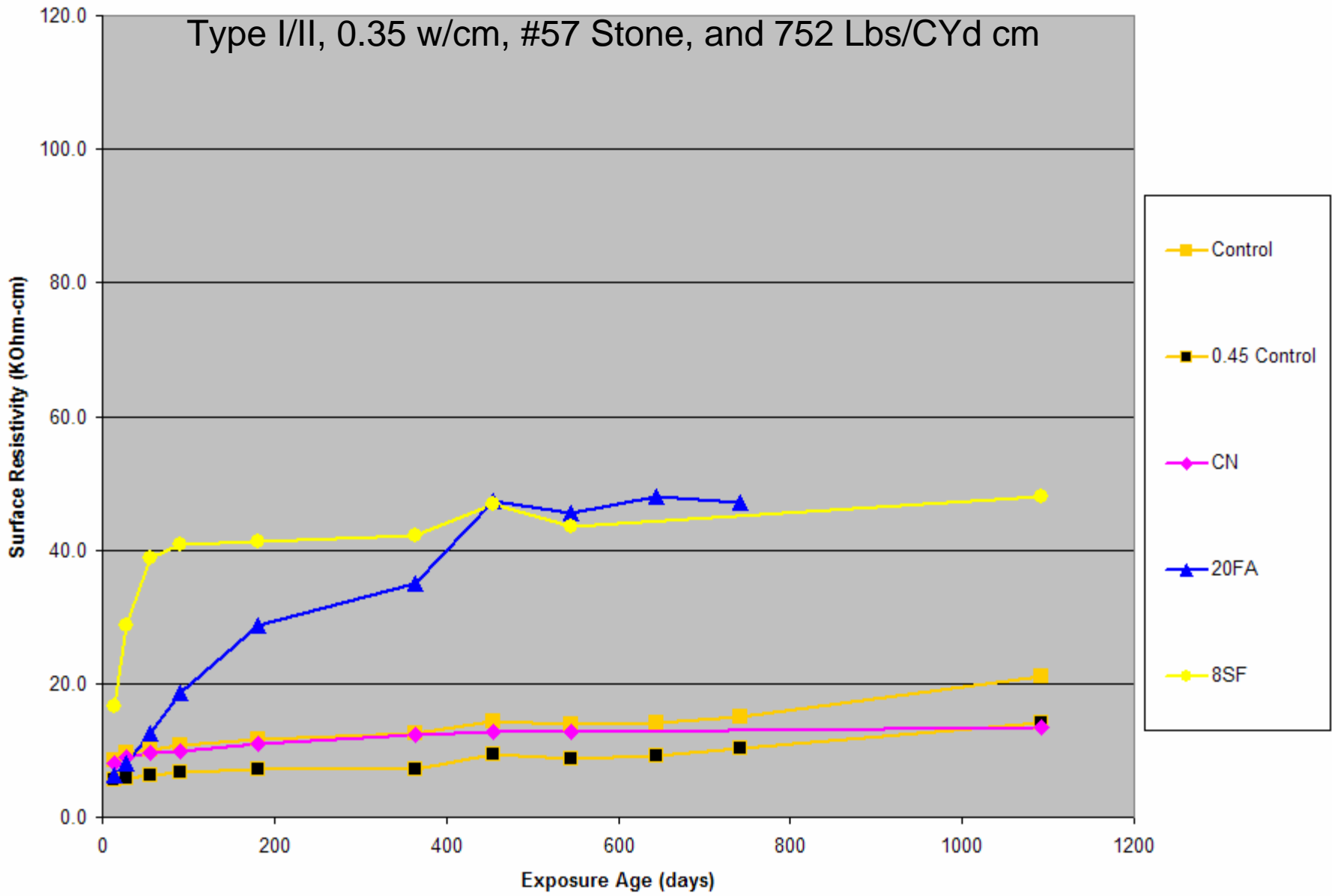
Relationship SR vs. RCP

FDOT Field Samples
RCP vs SR 28 day Correlation



Chini, A. et al

Type I/II, 0.35 w/cm, #57 Stone, and 752 Lbs/CYd cm



SR vs RCP Values

RCP versus Surface Resistivity

Chloride Ion Permeability	RCP Test Charged Passed (coulombs)	Surface Resistivity Test		
		4" X 8" (KOhm-cm) Spacing 1.5"	6" X 12" (KOhm-cm) Spacing 1.5"	Real
High	>4,000	< 12	< 9.5	< 6.7
Moderate	2,000-4,000	12 - 21	9.5 - 16.5	6.7 - 11.7
Low	1,000-2,000	21 - 37	16.5 - 29	11.7 - 20.6
Very Low	100-1,000	37 - 254	29 - 199	20.6 - 141.1
Negligible	<100	> 254	> 199	> 141.1

Precision of Methods

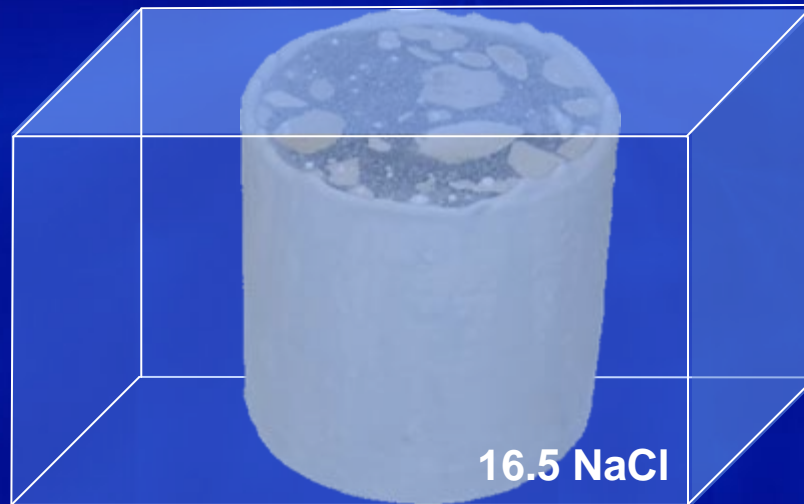
- Single-Operator Precision:
 - SR - The single operator coefficient of variation = 6.3%
 - RCP - The single operator coefficient of variation = 12.3%

Diffusion Test

Bulk Diffusion (NT Build 443)

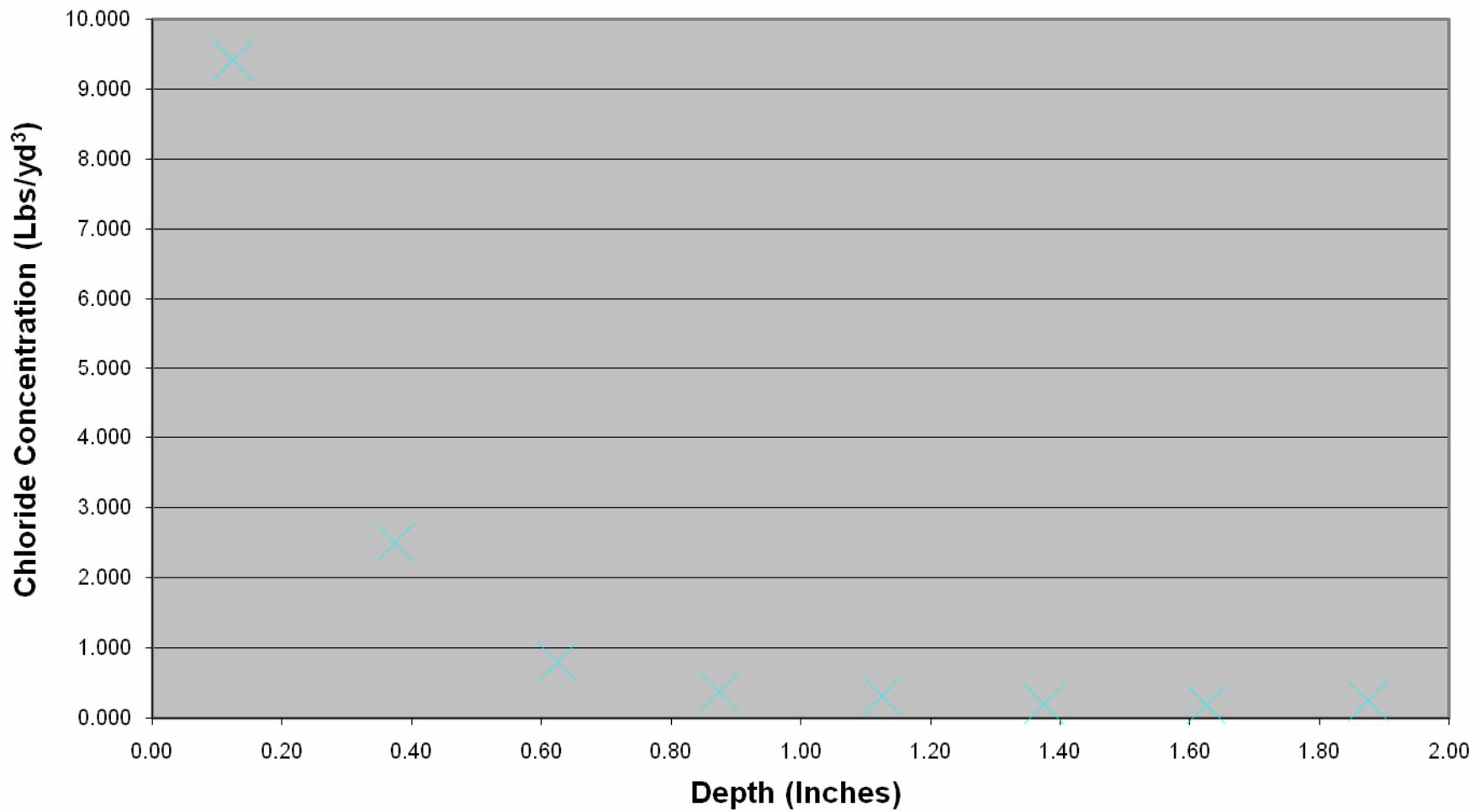


Cylinder is sliced at
364 (1 year) or 1092 (3 years) days of
exposure
for Chloride analysis.

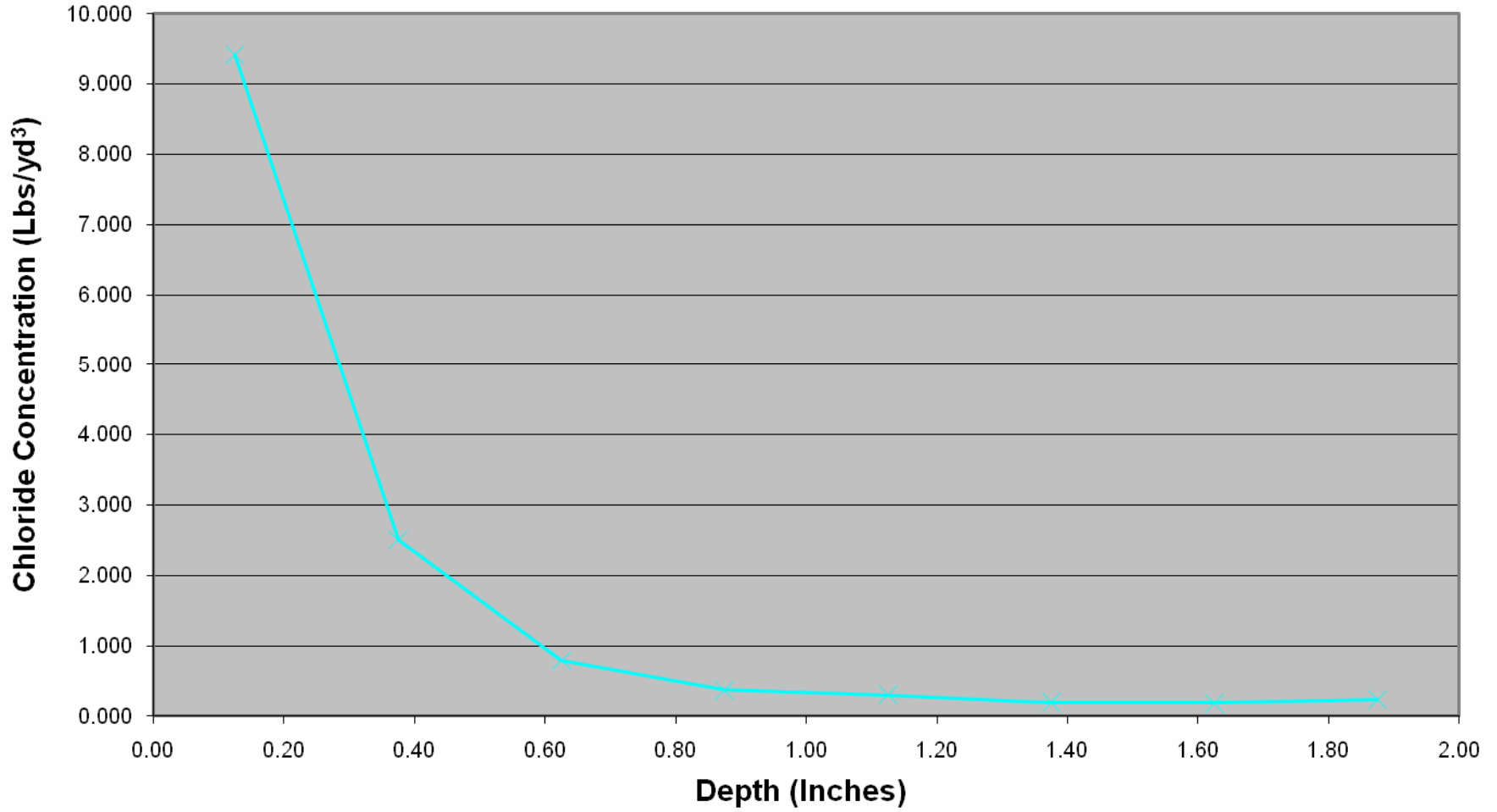


Each slice is
 $\frac{1}{4}$ in thick

Chloride Profile



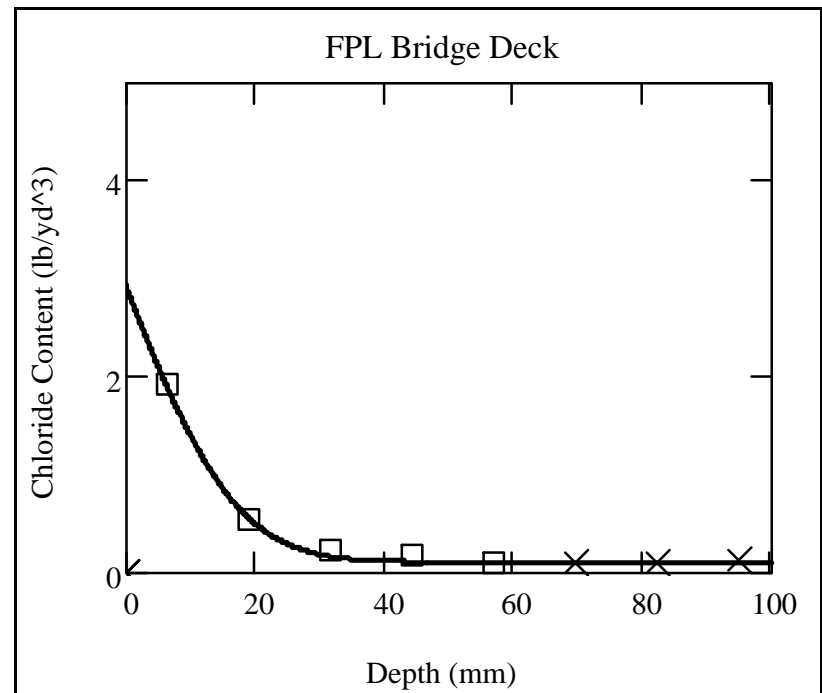
Chloride Profile



Analysis of Chloride Profile

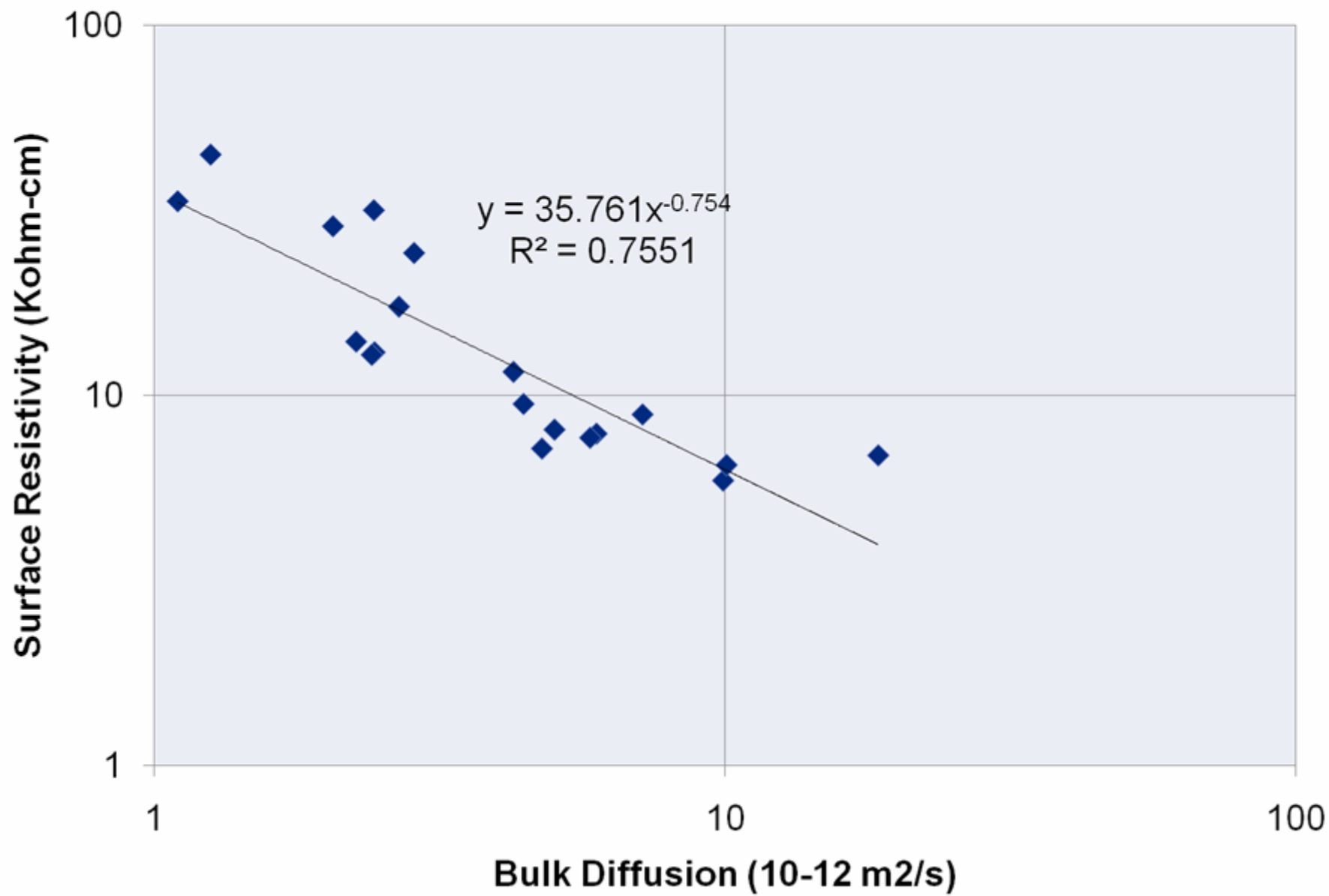
$$C(x,t) = C_s - (C_s - C_i) \operatorname{erf}\left(\frac{x}{\sqrt{4Dt}}\right)$$

$$C(x,a) := \left[\begin{array}{c} a_2 - (a_2 - C_i) \cdot \operatorname{erf}\left(\frac{x}{\sqrt{4 \cdot a_1 \cdot t}}\right) \\ \frac{1}{2} \cdot \frac{a_2 - C_i}{\frac{1}{\pi^2}} \cdot \exp\left(\frac{-1}{4} \cdot \frac{x^2}{a_1 \cdot t}\right) \cdot \frac{x}{\frac{1}{a_1 \cdot (a_1 \cdot t)^2}} \\ 1 - \operatorname{erf}\left(\frac{x}{\sqrt{4 \cdot a_1 \cdot t}}\right) \end{array} \right]$$

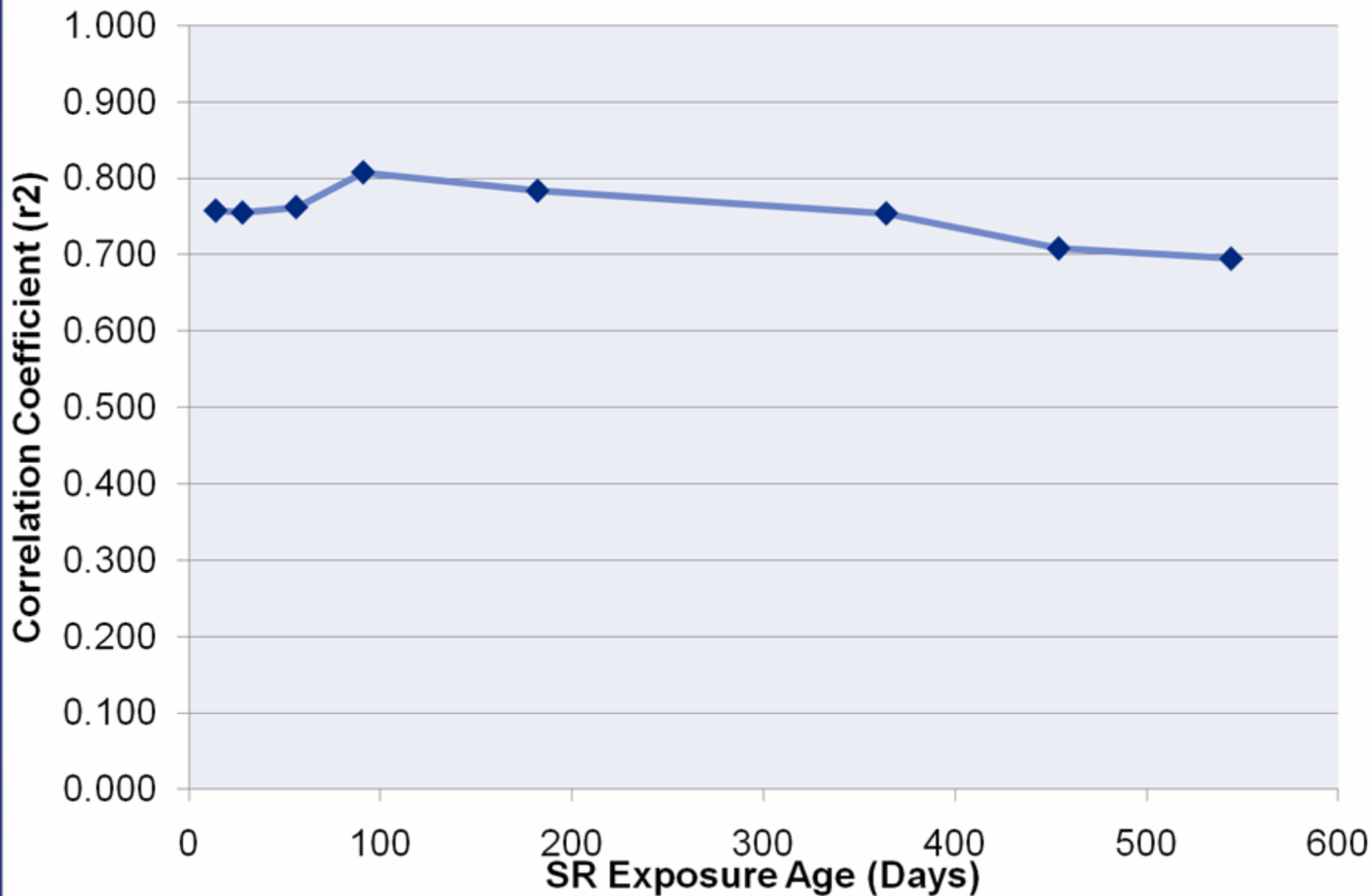


Diffusion(m ² /sec)	8.899E-14	Background(lb/yd ³)	0.100
Surface(lb/yd ³)	2.924	R ² Value	0.9985

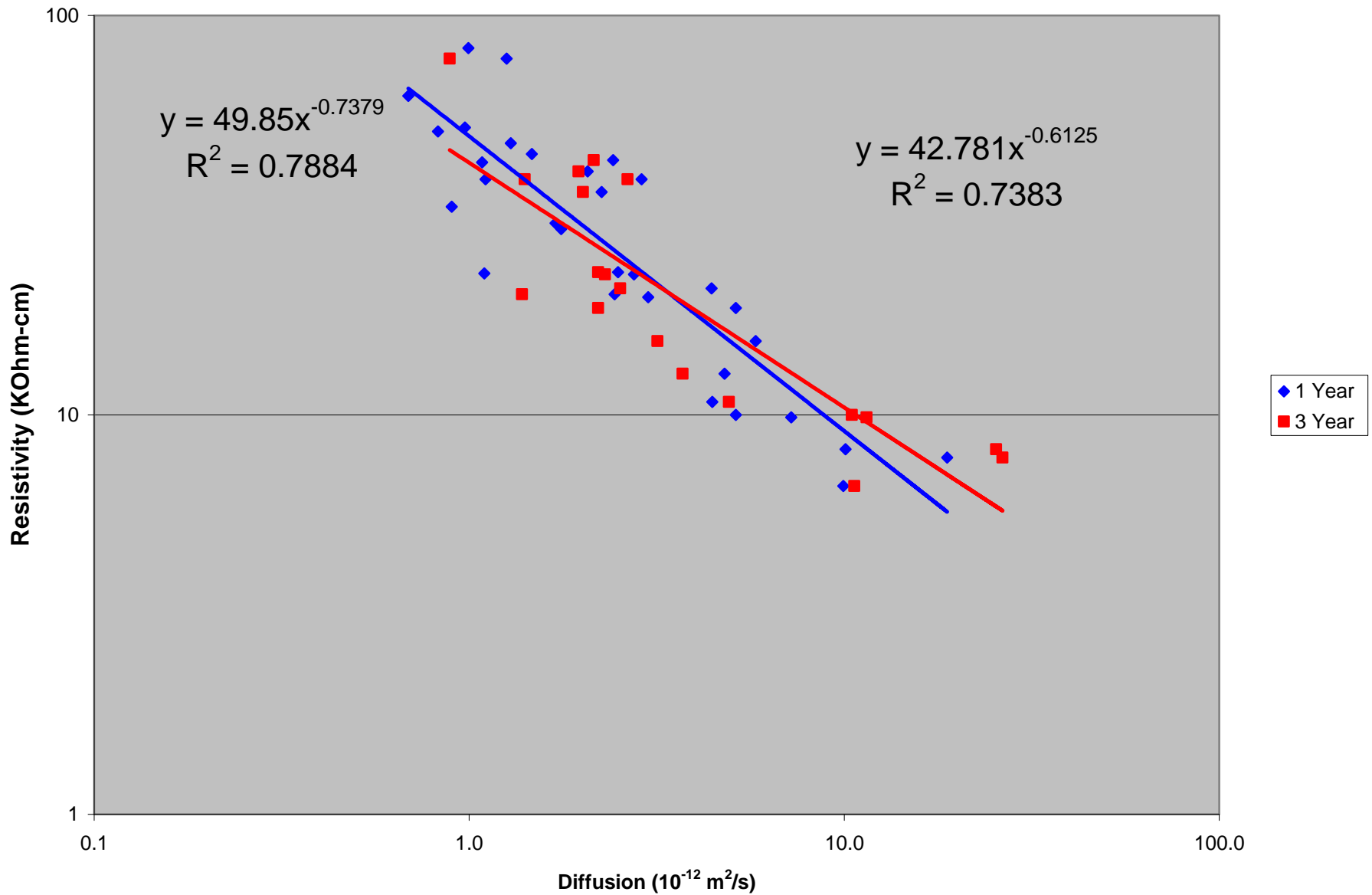
28 Day SR vs. 364 BD



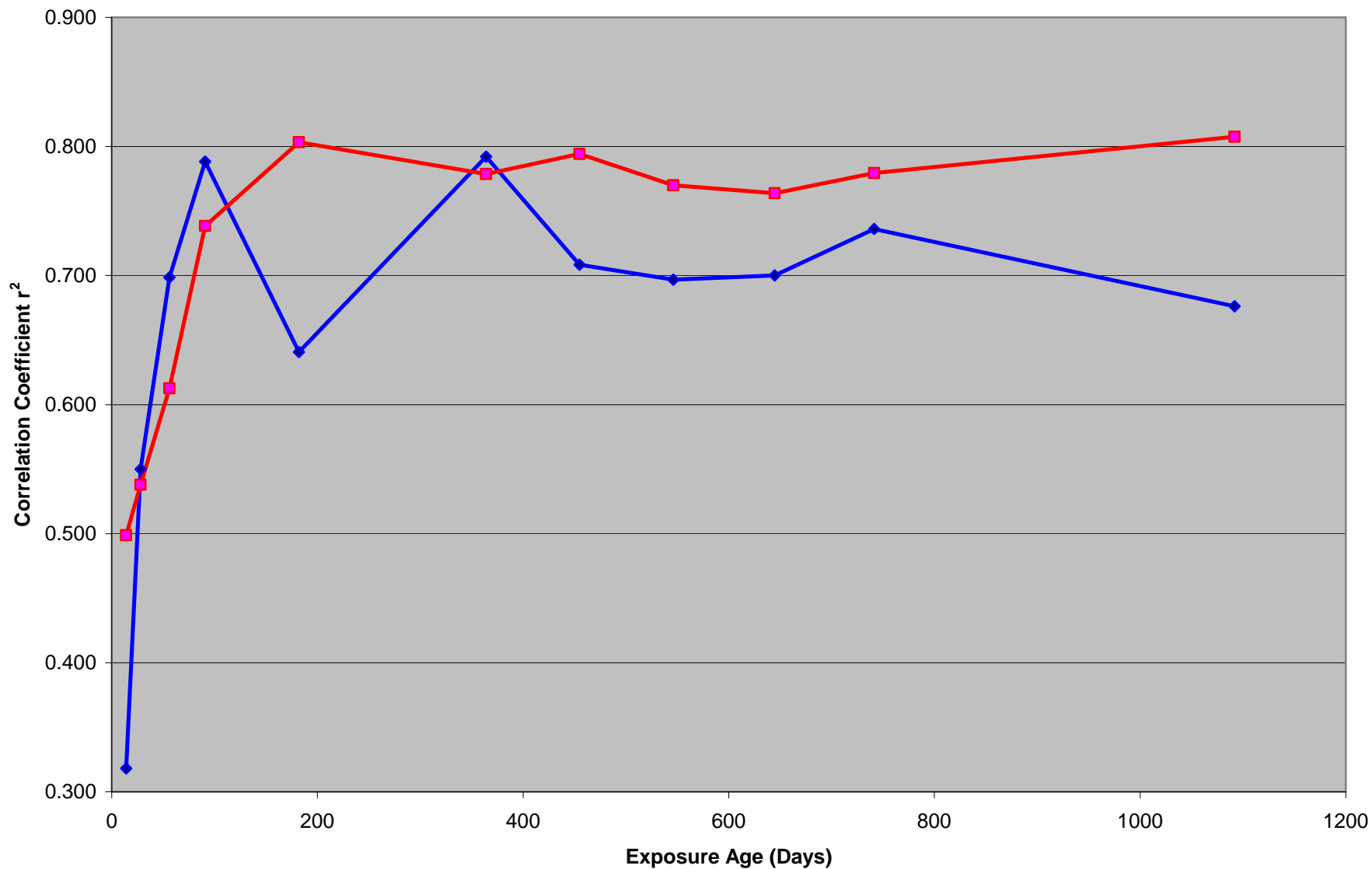
SR vs. 364 BD Correlation



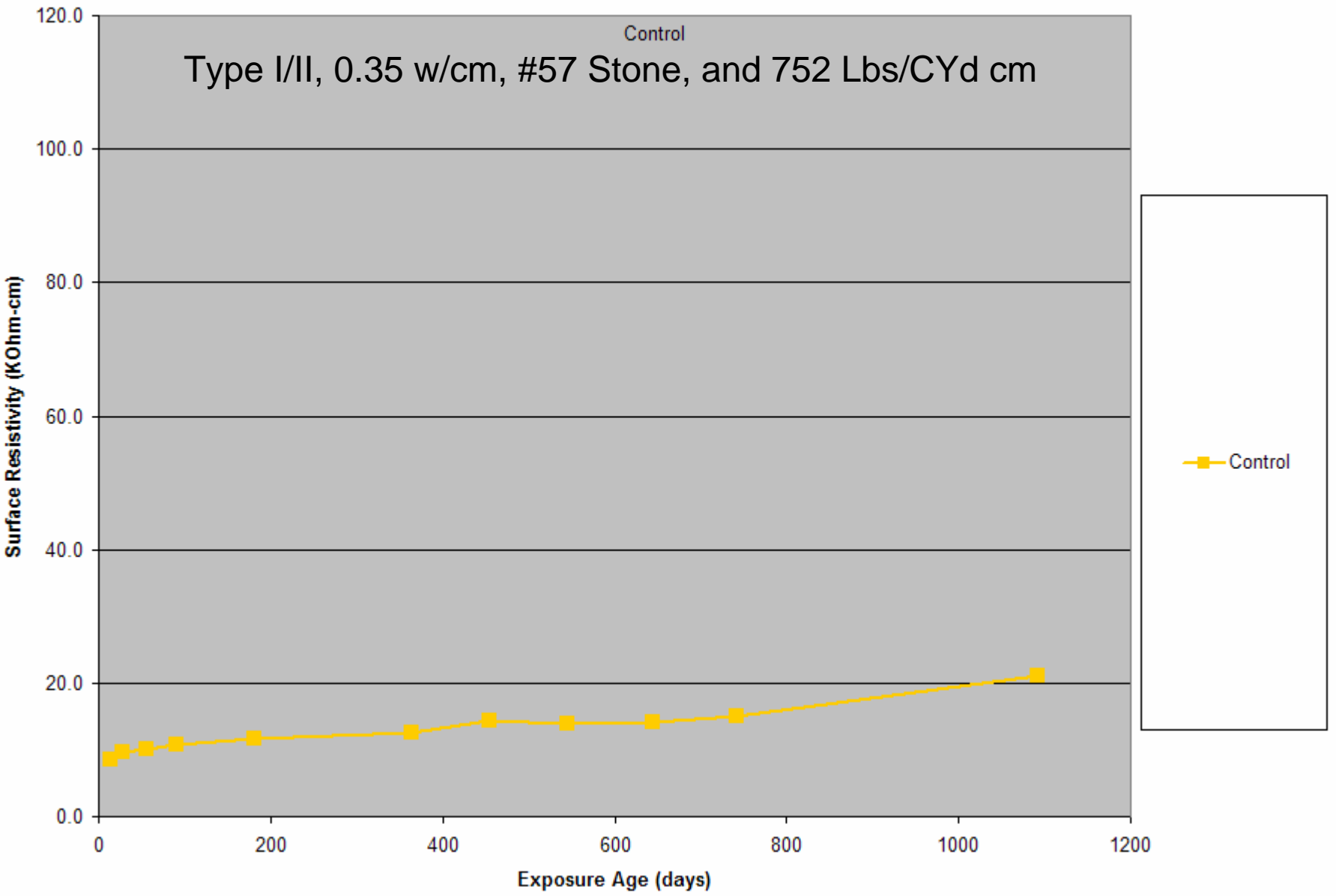
91 Day SR Correlation to 1 & 3 year BD



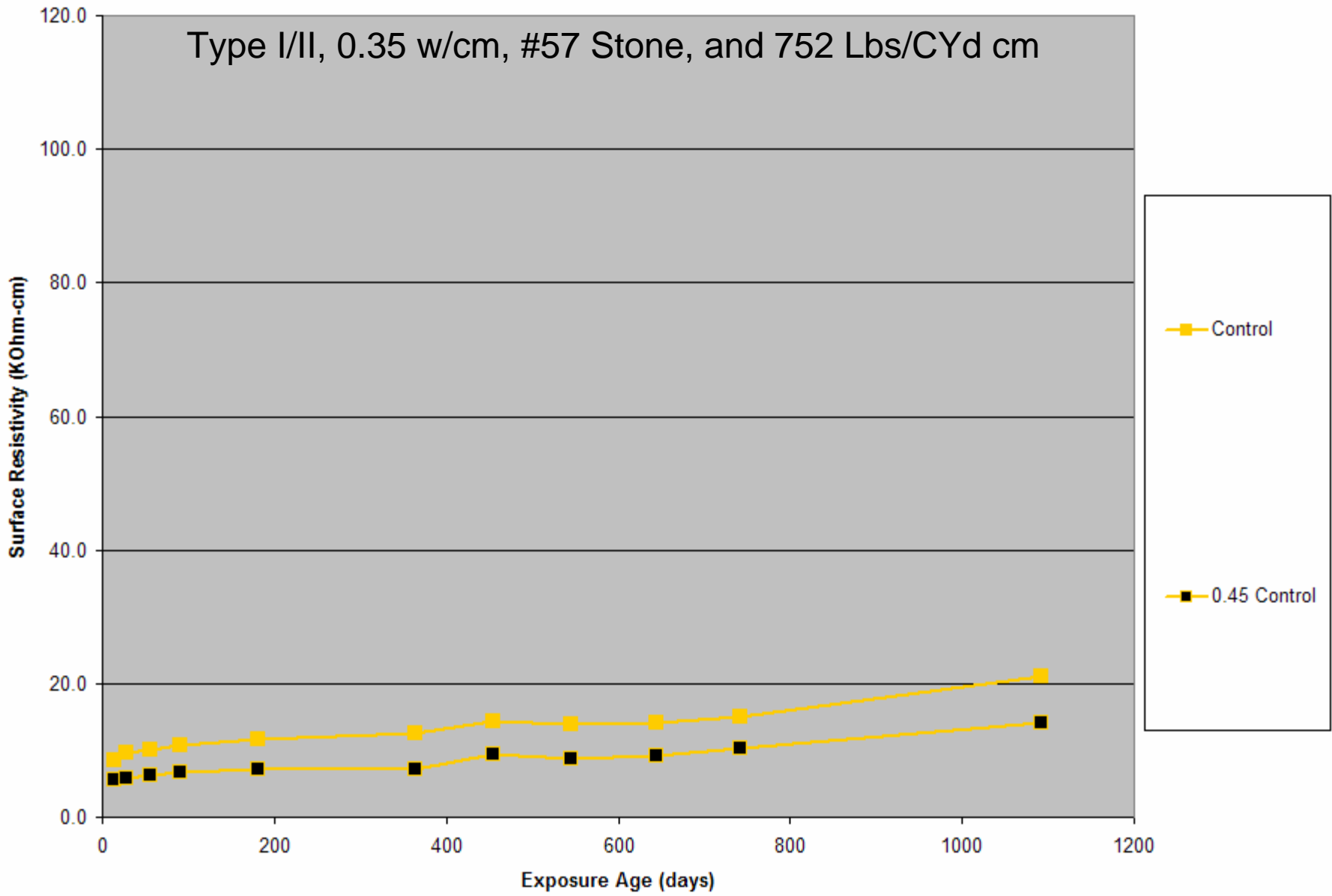
SR vs. BD Correlation Coefficient



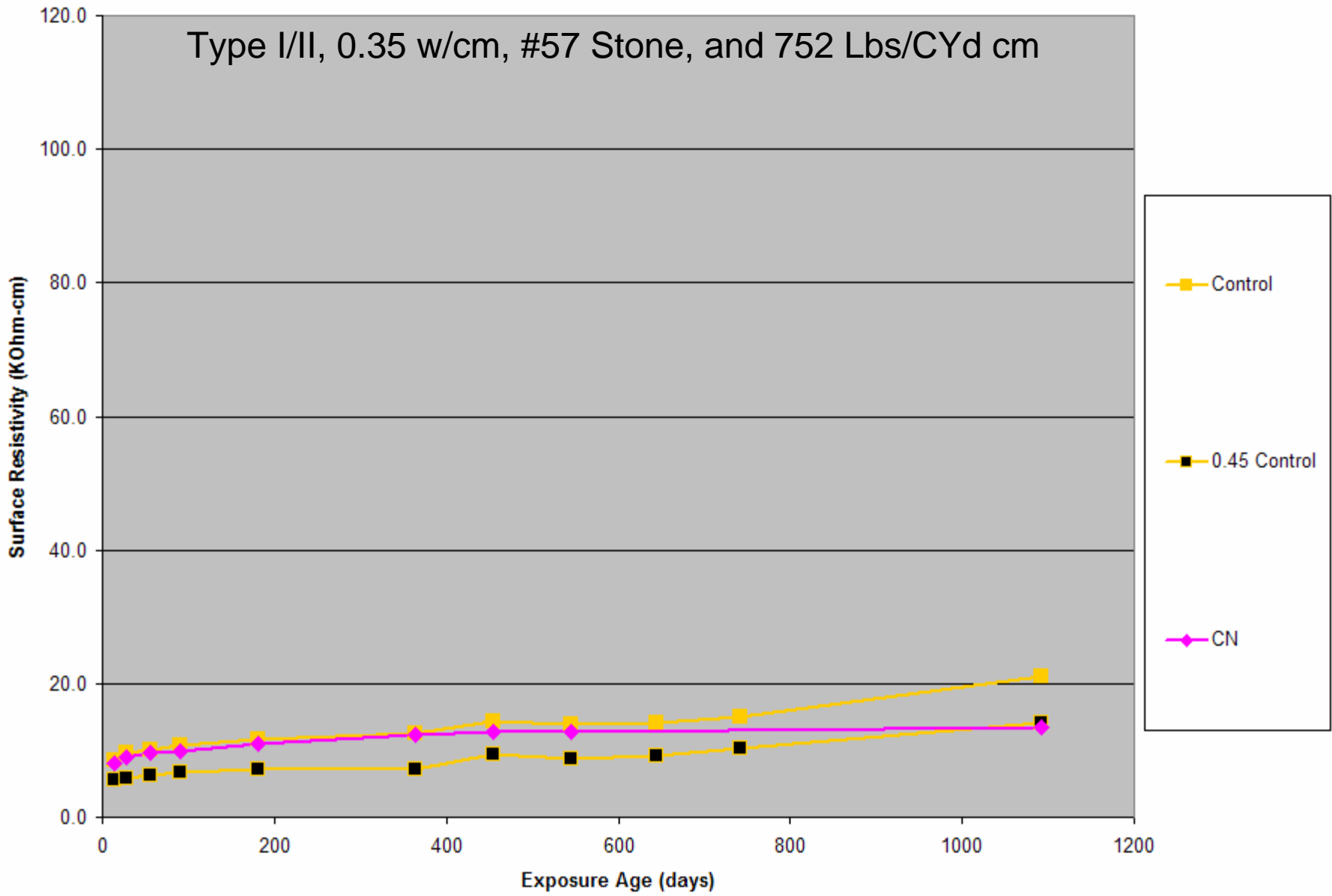
BD 1 Year Correlation BD 3 Year Correlation



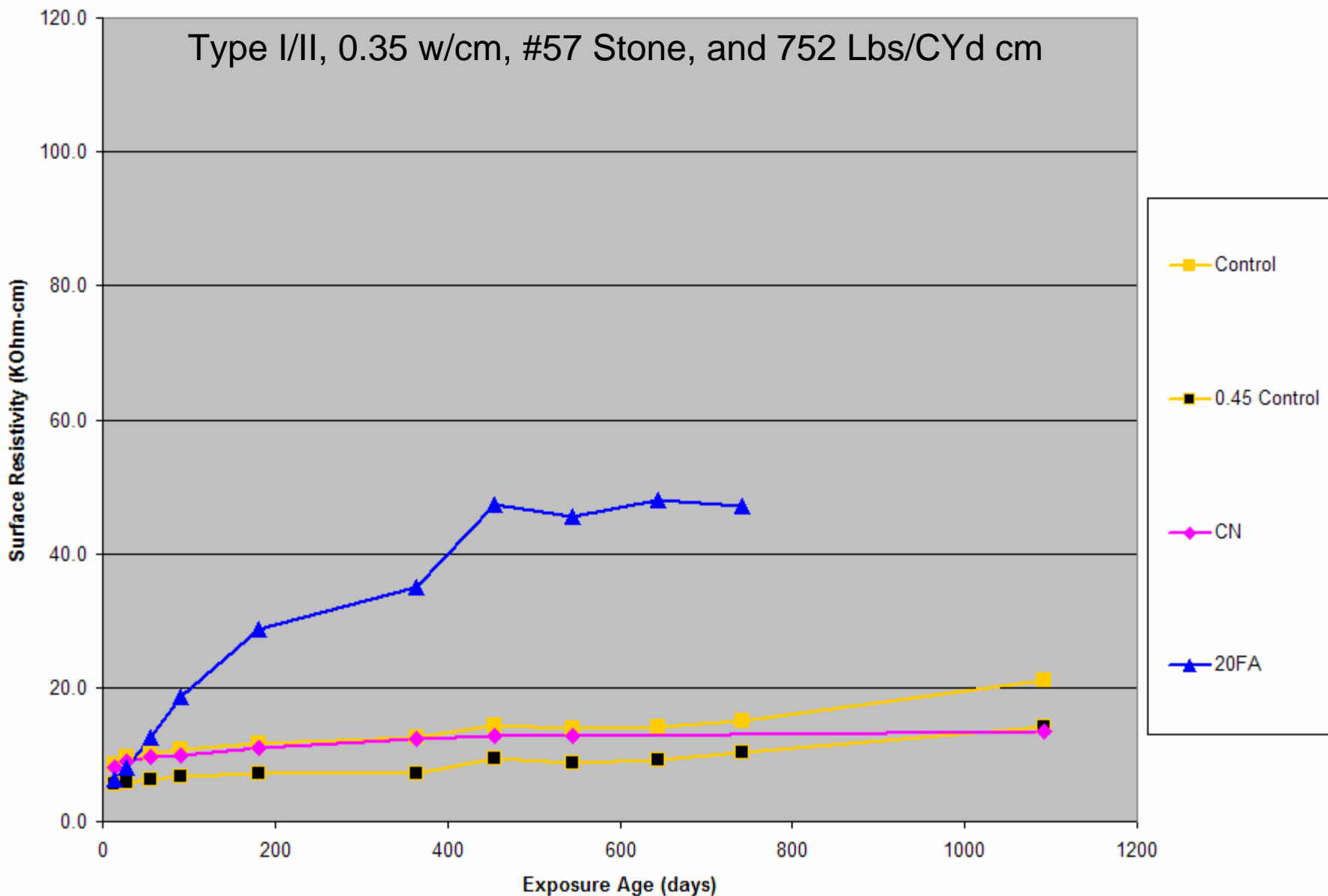
Type I/II, 0.35 w/cm, #57 Stone, and 752 Lbs/CYd cm



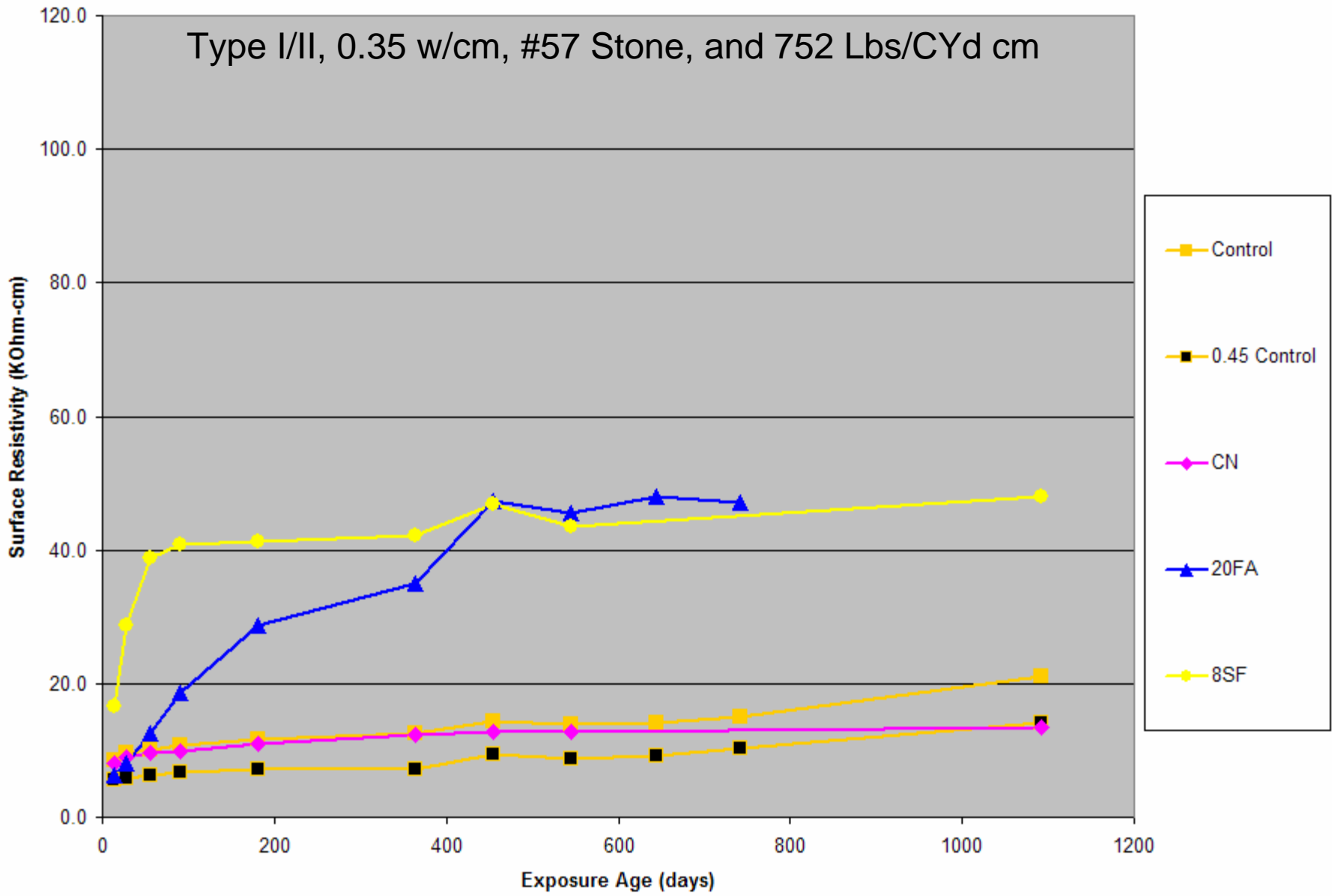
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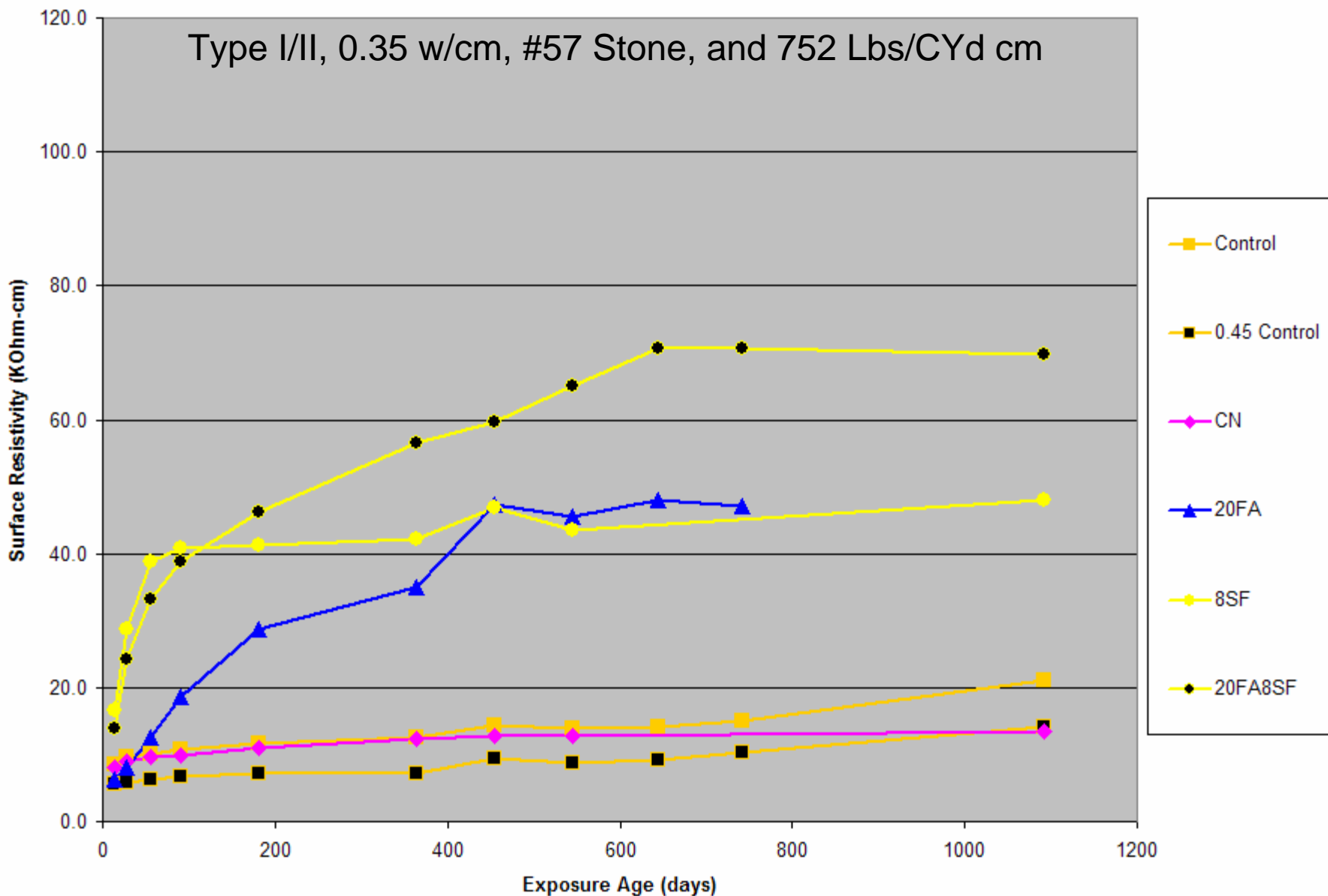
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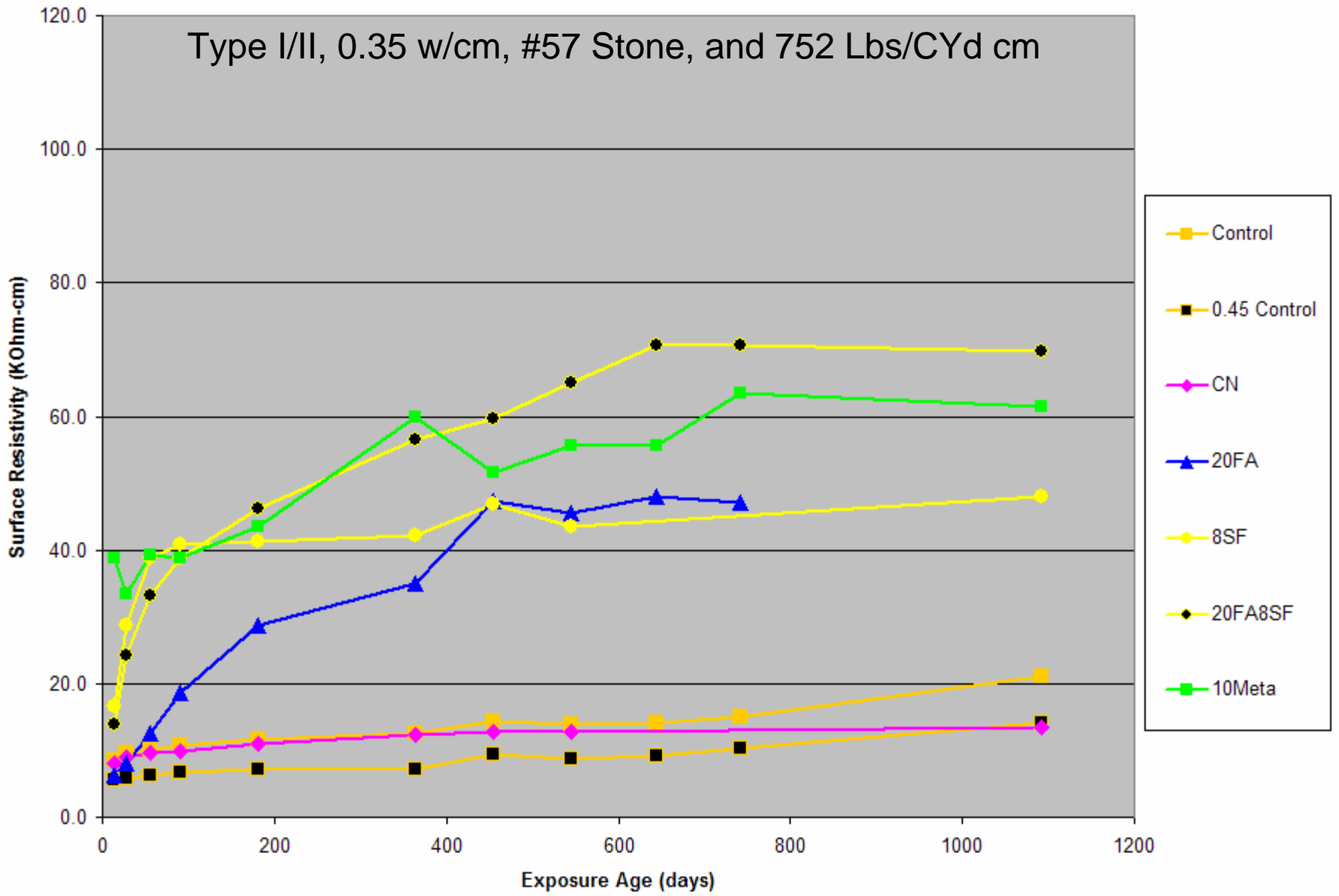
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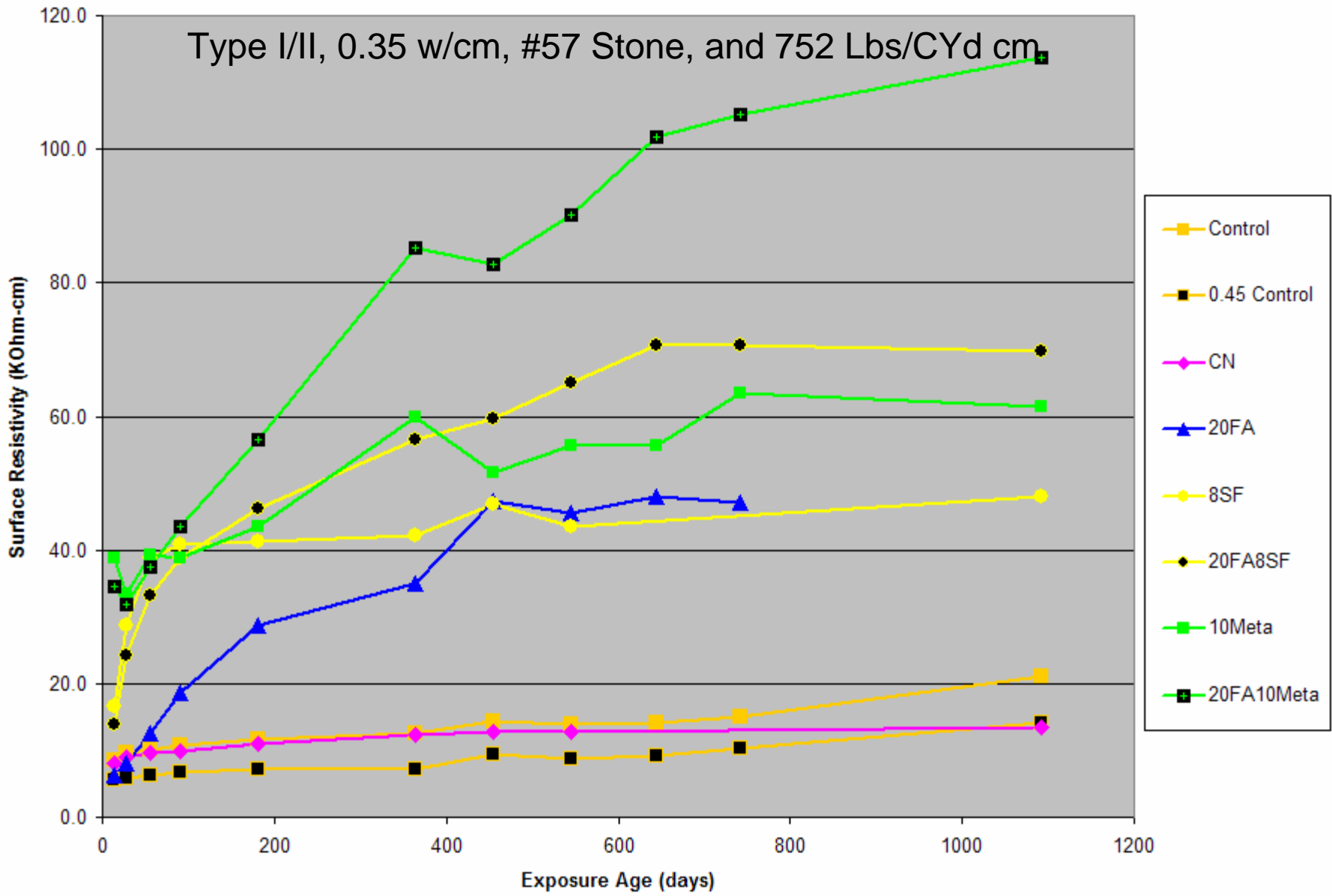
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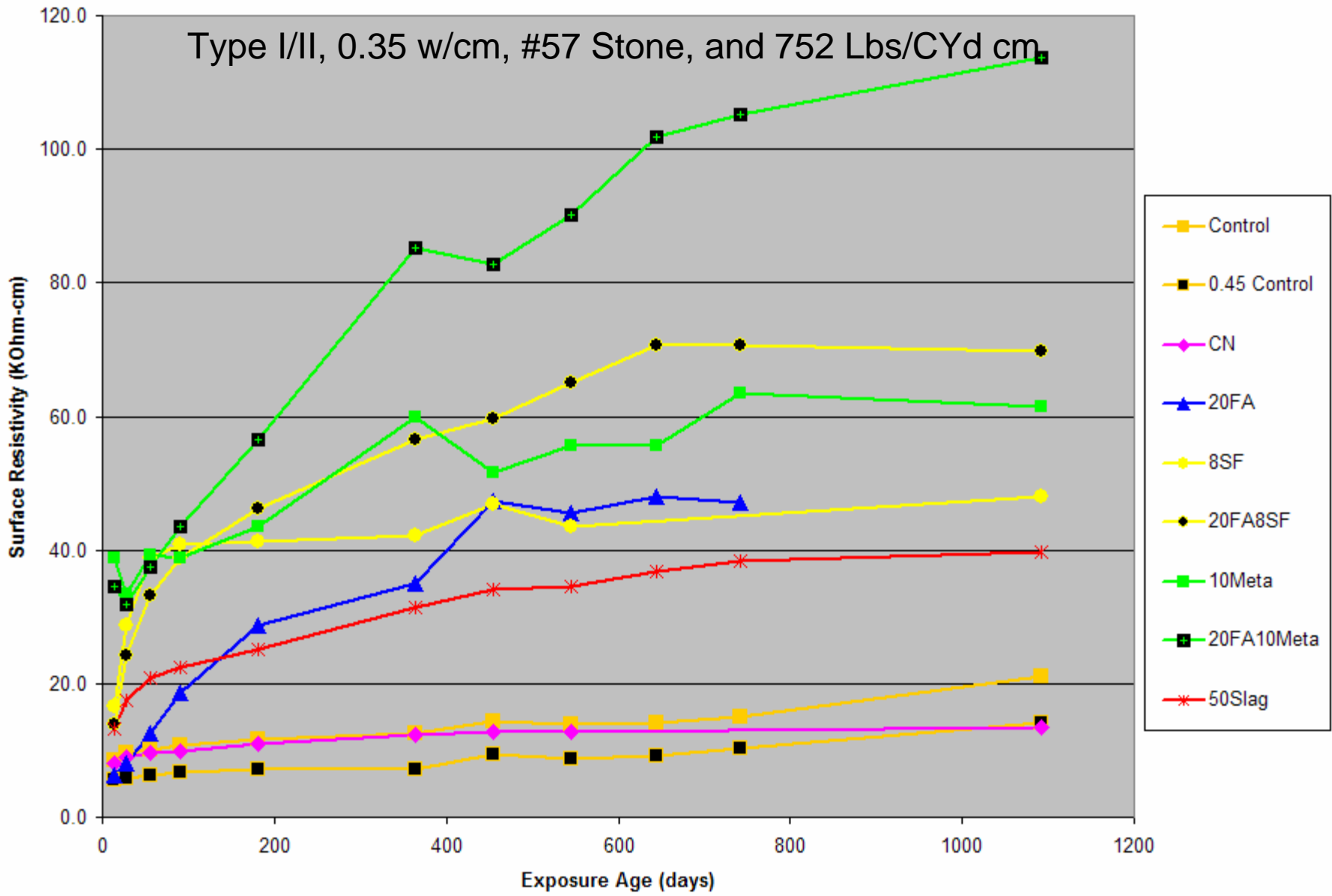
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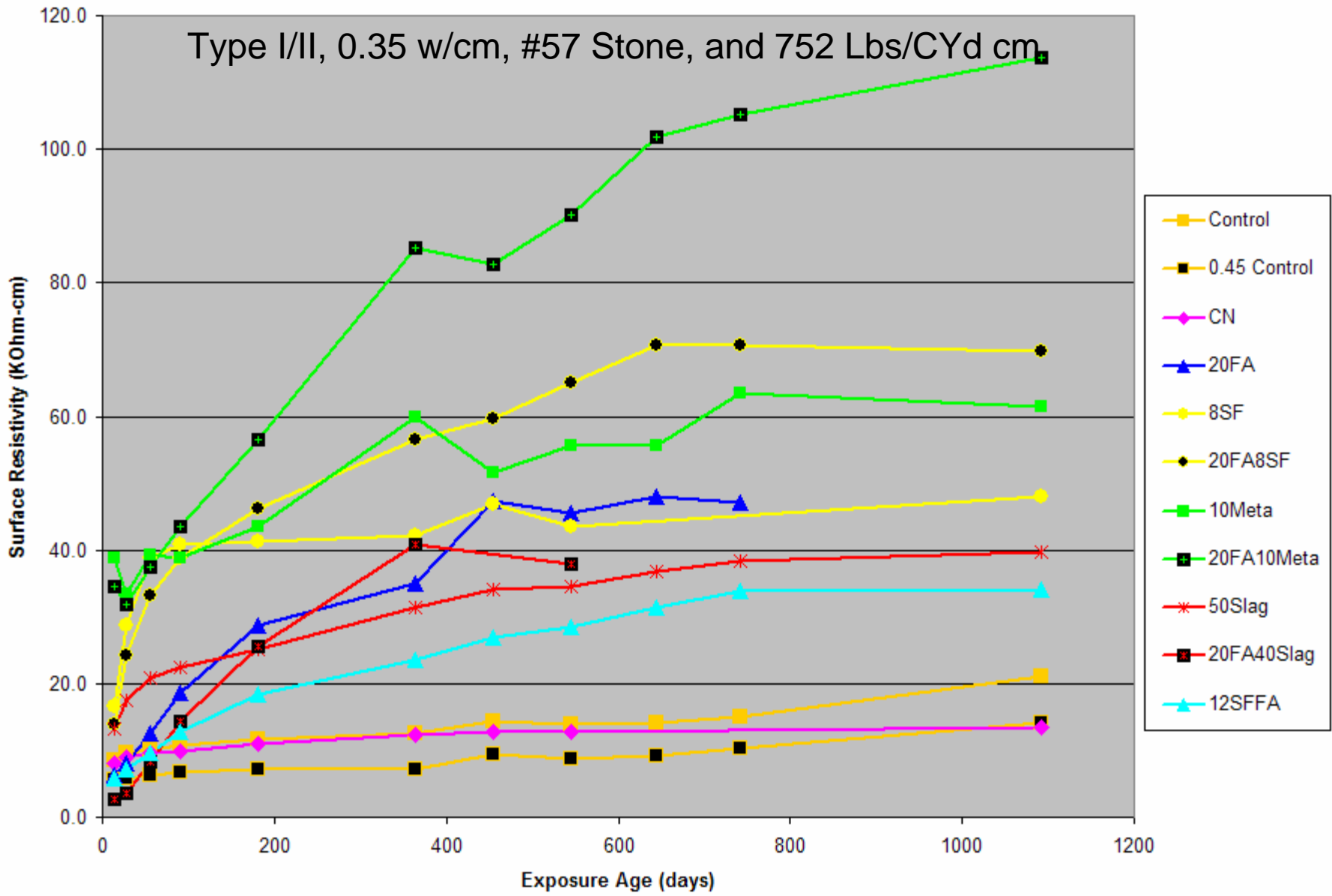
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Type I/II, 0.35 w/cm, #57 Stone, and 752 Lbs/CYd cm



Conclusions

- SR can be used as an electrical indicator of concrete chloride penetration resistance.
- Can be used as a QC test provided that its relationship to diffusion has been studied.
 - Concretes SF or Metakaolin could be tested at 28 days of curing age.
 - Concretes with FA or Slag at 91 or later.

Conclusions

- Diffusion of laboratory samples is one order magnitude higher than field samples.

Questions?