# MSE Wall Backfill Testing:

# Sample Preparation for Accurate Modeling

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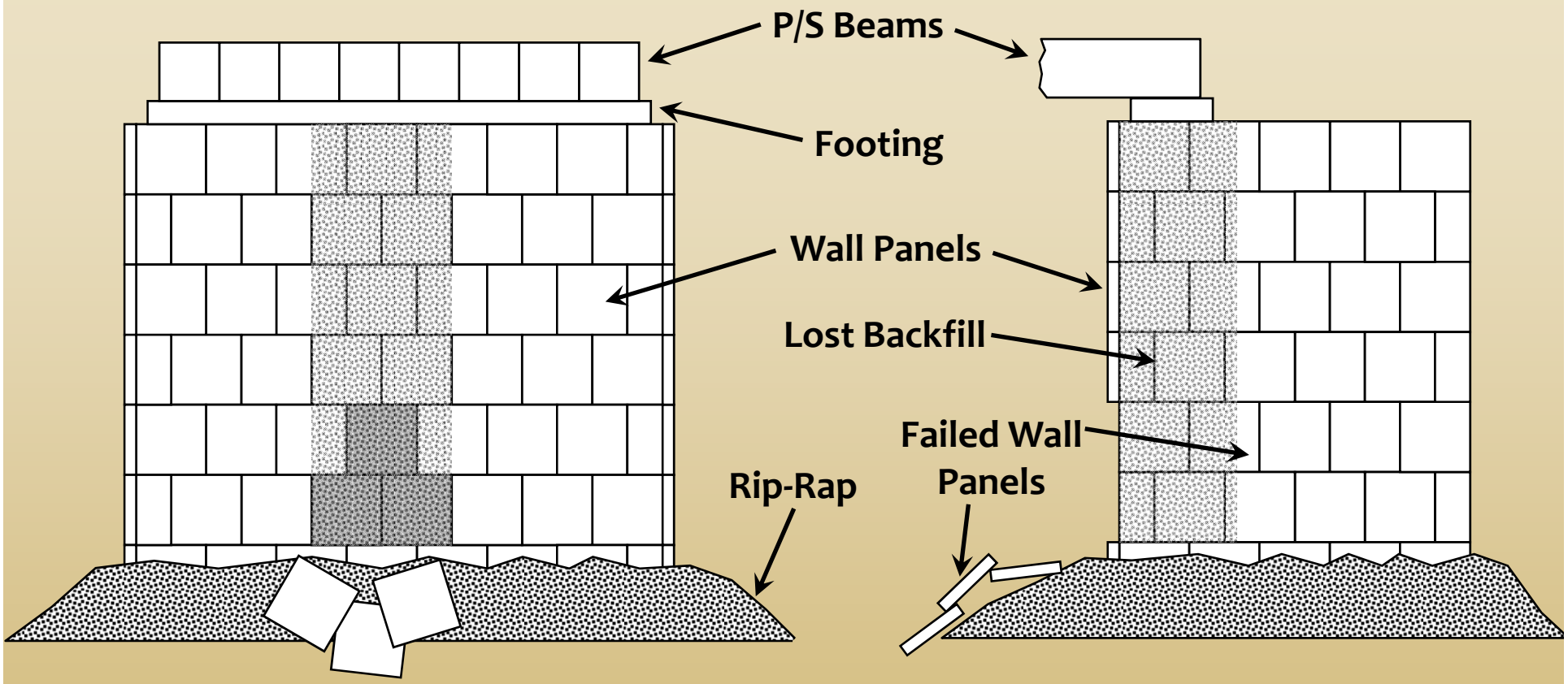
## Acknowledgements:


Brian Gutshall
Dave Kuniega
Patricia Milller
Dennis Neff
Tim Ramirez
Roy Trout
Winson King
Pat McGonagle
Paul Moffitt
Victoria Porto
Todd Sekela
Brenda Waters
Linda Wicks




# MSE Wall Failure

# Contributing Factors:

1) Connection Type
2) Filter Fabric Installation
3) Fines in Backfill

# Result:

1) Conservative approach in policy for use of MSE walls (no abutments)
2) Low allowable fines (5%)
3) Stricter electrochemical requirements

# Problem:

1) MSE Wall backfill materials often failing quality requirements
2) Resistivity (most common)
3) Chloride and Sulfate contents (lesser extent)

## Comparison to other agency requirements:

| MSE Wall Backfill Requirements | | |
|---|---|---|
| Specification Component | PENNDOT | Typical for Other Agencies |
| Chlorides (ppm) | < 100 | < 100 |
| Sulfates (ppm) | < 200 | < 200 |
| pH | 6 – 10 | 5 – 10 |
| Resistivity (ohm-cm) | > 5000 | > 3000 |
| Max. Fines Content (%) | 5 | 15 |

Other than fines, no major anomalies

Looked at test methods for electrochemical criteria:

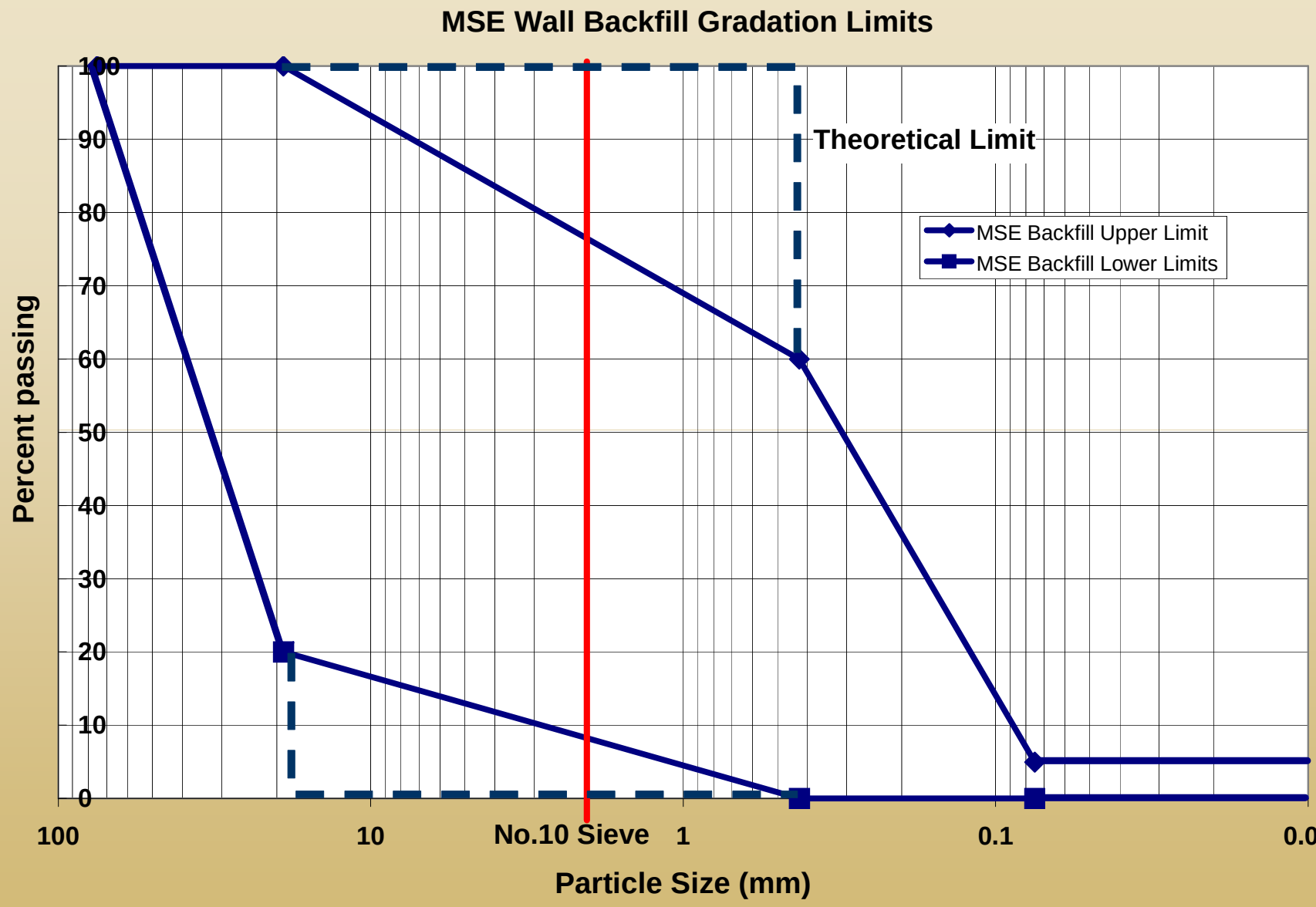
1) Resistivity - AASHTO T 288
2) pH - AASHTO T 289
3) Chloride Content – AASHTO T 290
4) Sulfate Content – AASHTO T 291

## AASHTO Test Methods:

1) Adopted from CALTRANS methods
2) Originally developed for testing soil
3) Require minus 10 material for testing (material passing the #10 sieve)

# PENNDOT MSE Gradation Requirements:

| Sieve | Percent Passing |
|---|---|
| 3 inch | 100 |
| 0.75 inch | 20 – 100 |
| # 40 | 0 – 60 |
| # 200 | 0 – 5 |

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# AASHTO Test Methods
# Versus
# Typical PENNDOT MSE Backfill

1) AASHTO - Requires minus 10 material for testing
2) PENNDOT backfill typically coarse for drainage (#57 aggregate common)
3) High percent plus 10 material
4) Are we misrepresenting material in testing?

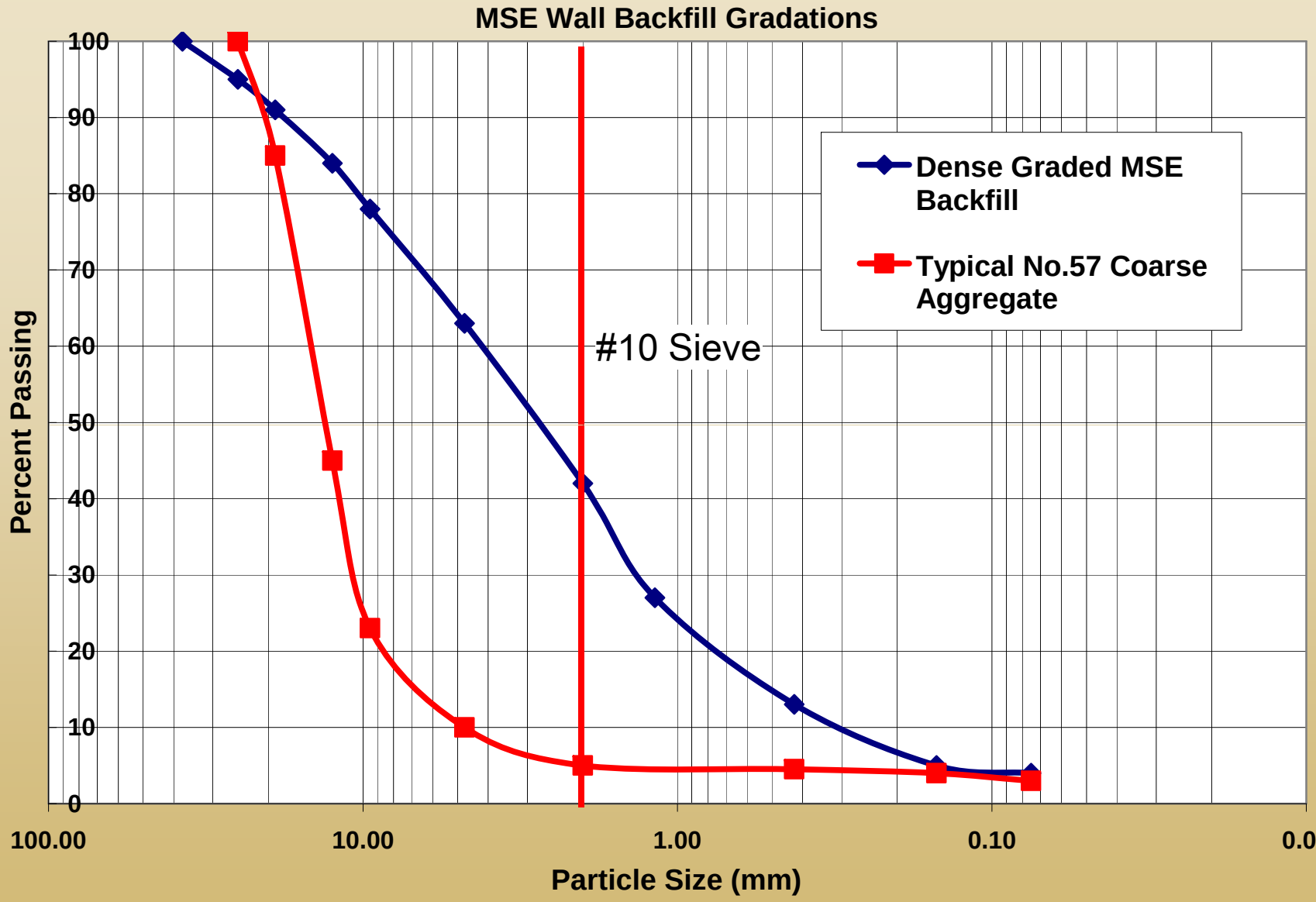


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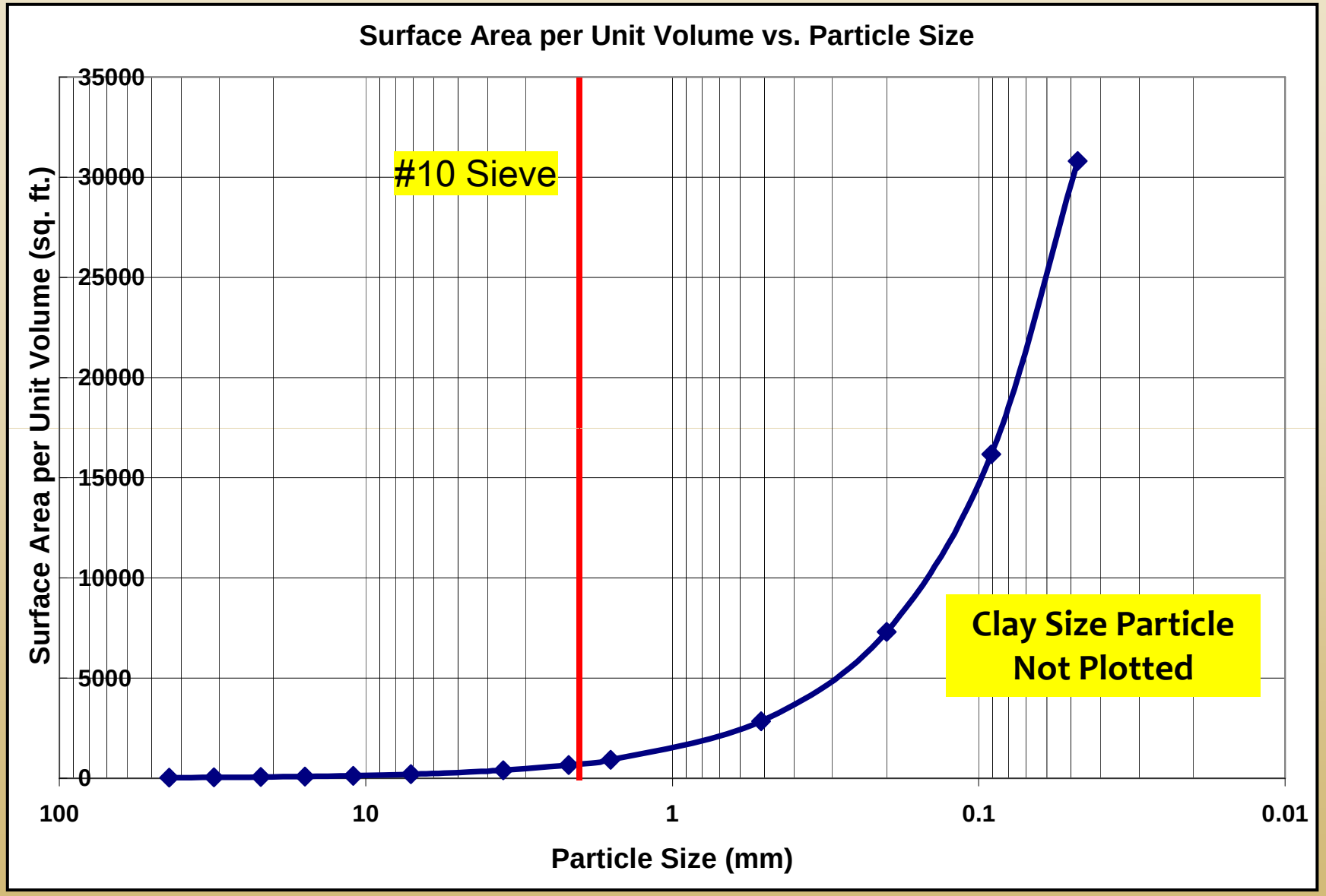
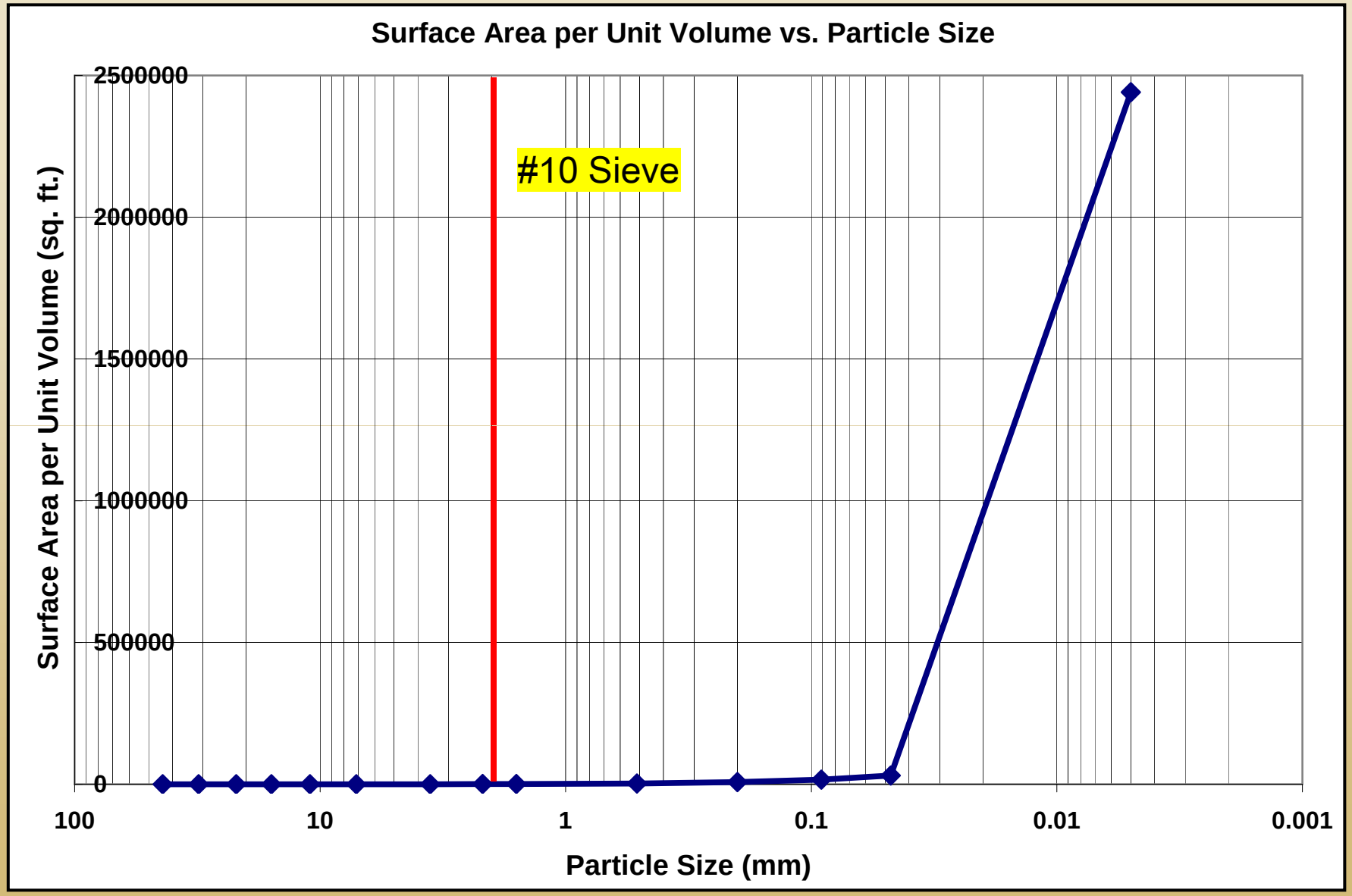
**Table D:** Particle Surface Area versus Number of Particles per Volume

| Sieve Size (mm) | Sieve Size (in or No.) | Average Particle Size Retained (mm) | Surface Area per Particle ($ft^2$) | Number Particles per cu. ft. material (assuming 20% voids) | Total Surface Area per cu. ft. material at 20% Voids ($ft^2$) |
|---|---|---|---|---|---|
| 37.5 | 1.5” | 43.8 | 6.47E-02 | 517 | 33.4 |
| 25.0 | 1.0” | 31.3 | 3.30E-02 | 1,418 | 46.8 |
| 19.0 | 0.75” | 22.0 | 1.64E-02 | 4,063 | 66.5 |
| 12.5 | 0.5” | 15.8 | 8.39E-03 | 11,074 | 92.9 |
| 9.5 | 3/8” | 11.0 | 4.09E-03 | 32,506 | 133 |
| 4.75 | #4 | 7.13 | 1.72E-03 | 119,614 | 205 |
| 2.36 | #8 | 3.56 | 4.27E-04 | 962,978 | 412 |
| 2.0 | #10 | 2.18 | 1.61E-04 | 4,176,051 | 671 |
| 1.18 | #16 | 1.59 | 8.55E-05 | 10,763,261 | 920 |
| 0.425 | #40 | 0.513 | 8.88E-06 | 321,405,740 | 2,855 |
| 0.15 | #100 | 0.20 | 1.35E-06 | 5,408,106,683 | 7,315 |
| 0.075 | #200 | 0.091 | 2.77E-07 | 58,369,973,952 | 16,166 |
| <0.075 | <#200 | 0.0475 | 7.63E-08 | 403,695,964,671 | 30,801 |
| Colloid – Clay Part. | | 0.005 | 4.23E-10 | 5.77E+15 | 2,441,000 |

**Assumes spherical particle and 20% voids**


Surface Area per Unit Volume vs. Particle Size
Surface Area per Unit Volume (sq. ft.)
35000
30000
25000
20000
15000
10000
5000
0
#10 Sieve
Clay Size Particle
Not Plotted
100
10
1
0.1
0.01
Particle Size (mm)


Surface Area per Unit Volume vs. Particle Size
Surface Area per Unit Volume (sq. ft.)
2500000
2000000
1500000
1000000
500000
0
#10 Sieve
100
10
1
0.1
0.01
0.001
Particle Size (mm)

Assumes spherical particle and 20% voids

# Gradation versus Surface Area – No. 57 Coarse Aggregate

| Sieve Size (mm) | Sieve Size (No.) | Avg. Size Ret. (mm) | Surf. Area per Part. | Full Gradation | | | Minus No. 10 Only | | | Coarse Sub. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % Ret. | % Surf. Area | sq. ft. per cu. ft. | % Ret. | % Surf. Area | sq. ft. per cu. ft. | % Ret. | % Surf. Area | sq. ft. per cu. ft. |
| 2.36 | 8 | | | 95* | 9.5 | 121 | | | | | | |
| 2.0 | 10 | 2.18 | 1.6E-4 | | | | | | | 95 | 35.5 | 638 |
| 1.18 | 16 | 1.59 | 8.6E-5 | | | | | | | | | |
| 0.425 | 40 | 0.51 | 8.9E-6 | | | | 10 | 1.3 | 285 | | | |
| 0.15 | 100 | 0.20 | 1.4E-6 | 1 | 5.7 | 73 | 10 | 3.2 | 732 | 1 | 4.1 | 73 |
| 0.075 | 200 | 0.091 | 2.8E-7 | 1 | 12.6 | 162 | 20 | 14.2 | 3233 | 1 | 9.0 | 162 |
| <0.075 | <200 | 0.048 | 7.6E-8 | 3 | 72.2 | 924 | 60 | 81.3 | 18,481 | 3 | 51.4 | 924 |
| | | | | 100 | 100 | 1280 | 100 | 100 | 22,731 | 100 | 100 | 1796 |

* Plus 8 material (up to 1.5 inch max size)

Assumes spherical particle and 20% voids

# Gradation versus Surface Area – Dense Graded MSE

| Sieve Size (mm) | Sieve Size (No.) | Avg. Size Ret. (mm) | Surf. Area per Part. | Full Gradation | | | Minus No. 10 Only | | | Coarse Sub. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % Ret. | % Surf. Area | sq. ft. per cu. ft. | % Ret. | % Surf. Area | sq. ft. per cu. ft. | % Ret. | % Surf. Area | sq. ft. per cu. ft. |
| 2.36 | 8 | | | 37* | 1.9 | 51 | | | | | | |
| 2.0 | 10 | 2.18 | 1.6E-4 | 21 | 5.2 | 141 | | | | 58 | 13.4 | 389 |
| 1.18 | 16 | 1.59 | 8.6E-5 | 15 | 5.1 | 138 | 35.8 | 5.5 | 329 | 15 | 4.8 | 138 |
| 0.425 | 40 | 0.51 | 8.9E-6 | 14 | 14.8 | 400 | 33.0 | 15.8 | 942 | 14 | 13.8 | 400 |
| 0.15 | 100 | 0.20 | 1.4E-6 | 8 | 21.6 | 585 | 19.0 | 23.3 | 1390 | 8 | 20.1 | 585 |
| 0.075 | 200 | 0.091 | 2.8E-7 | 1 | 6.0 | 162 | 2.4 | 6.5 | 388 | 1 | 5.6 | 162 |
| <0.075 | <200 | 0.048 | 7.6E-8 | 4 | 45.5 | 1232 | 9.5 | 49.0 | 2926 | 4 | 42.4 | 1232 |
| | | | | 100 | 100 | 2709 | 100 | 100 | 5975 | 100 | 100 | 2906 |

* Plus 8 material (up to 1.5 inch max size)

With 1% by weight of Clay

# Gradation versus Surface Area – Dense Graded MSE

| Sieve Size (mm) | Sieve Size (No.) | Avg. Size Ret. (mm) | Surf. Area per Part. | Full Gradation | | | Minus No. 10 Only | | | Coarse Sub. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % Ret. | % Surf. Area | sq. ft. per cu. ft. | % Ret. | % Surf. Area | sq. ft. per cu. ft. | % Ret. | % Surf. Area | sq. ft. per cu. ft. |
| 2.36 | 8 | | | 37* | 0.18 | 51 | | | | | | |
| 2.0 | 10 | 2.18 | 1.6E-4 | 21 | 0.53 | 141 | | | | 58 | 1.44 | 389 |
| 1.18 | 16 | 1.59 | 8.6E-5 | 15 | 0.52 | 138 | 35.8 | 0.52 | 329 | 15 | 0.51 | 138 |
| 0.425 | 40 | 0.51 | 8.9E-6 | 14 | 1.49 | 400 | 33.0 | 1.48 | 942 | 14 | 1.48 | 400 |
| 0.15 | 100 | 0.20 | 1.4E-6 | 8 | 2.18 | 585 | 19.0 | 2.18 | 1390 | 8 | 2.17 | 585 |
| 0.075 | 200 | 0.091 | 2.8E-7 | 1 | 0.60 | 162 | 2.4 | 0.61 | 388 | 1 | 0.60 | 162 |
| <0.075 | <200 | 0.048 | 7.6E-8 | 3 | 3.45 | 924 | 7.1 | 3.43 | 2187 | 3 | 3.42 | 924 |
| Clay - Colloid | | 0.005 | 4E-10 | 1 | 91.0 | 24,384 | 2.4 | 91.8 | 55,522 | 1 | 90.4 | 24,384 |
| | | | | 100 | 100 | 26,784 | 100 | 100 | 63,758 | 100 | 100 | 26,982 |

* Plus 8 material (up to 1.5 inch max size)

# Implication

1) Surface area analysis suggests that current method of sample preparation significantly misrepresents material as placed during construction
2) Does the change in relative sample surface area impact test results for electrochemical testing?

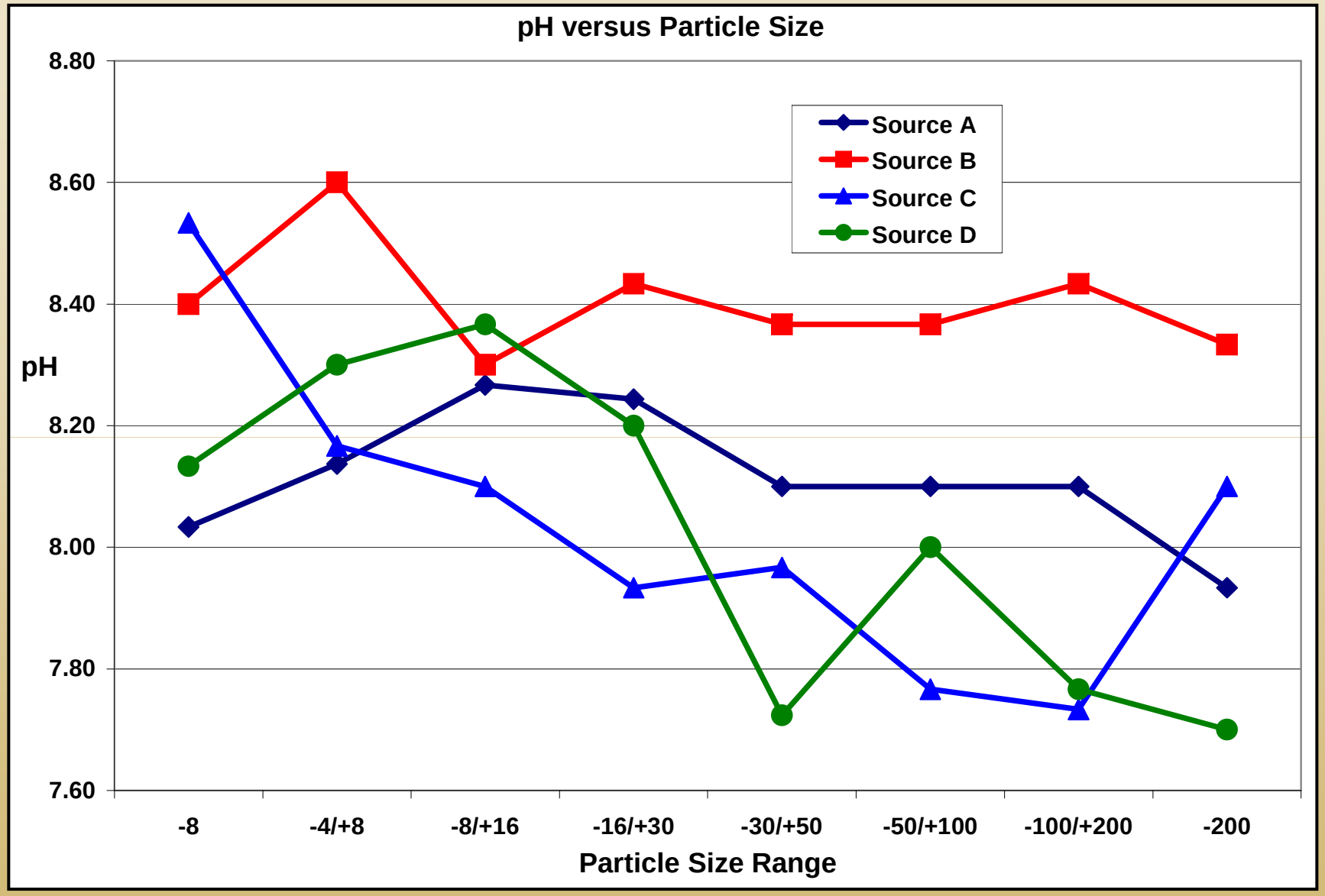
# Expectation

1) Suspect impact for resistivity, Chloride and Sulfate contents due to increase surface area and increased free ions
2) Likely minimal impact on pH since no change in chemistry if material is uniform across grain sizes.

# Laboratory Verification Study

1) Test material as per standard method
2) Test individual sieve fractions to assess impact of particle size (surface area)
3) Run tests on various material sources
4) Test for resistivity, chloride and sulfate contents, and pH

| Sieve and Particle Size Windows for MSE Backfill Electrochemical Study | |
|---|---|
| Sieve Windows | Particle Size Range (mm) |
| Minus No.8 Composite Sample (Normal Procedure) | Less Than 2.36 mm |
| -4/+8 | < 4.75 mm and > 2.36 mm |
| -8/+16 | < 2.36 mm and > 1.18 mm |
| -16/+30 | < 1.18 mm and > 0.600 mm |
| -30/+50 | < 0.600 mm and > 0.300 mm |
| -50/+100 | < 0.300 mm and > 0.150 mm |
| -100/+200 | < 0.150 mm and > 0.075 mm |
| Minus No.200 Material | Less than 0.075 mm |

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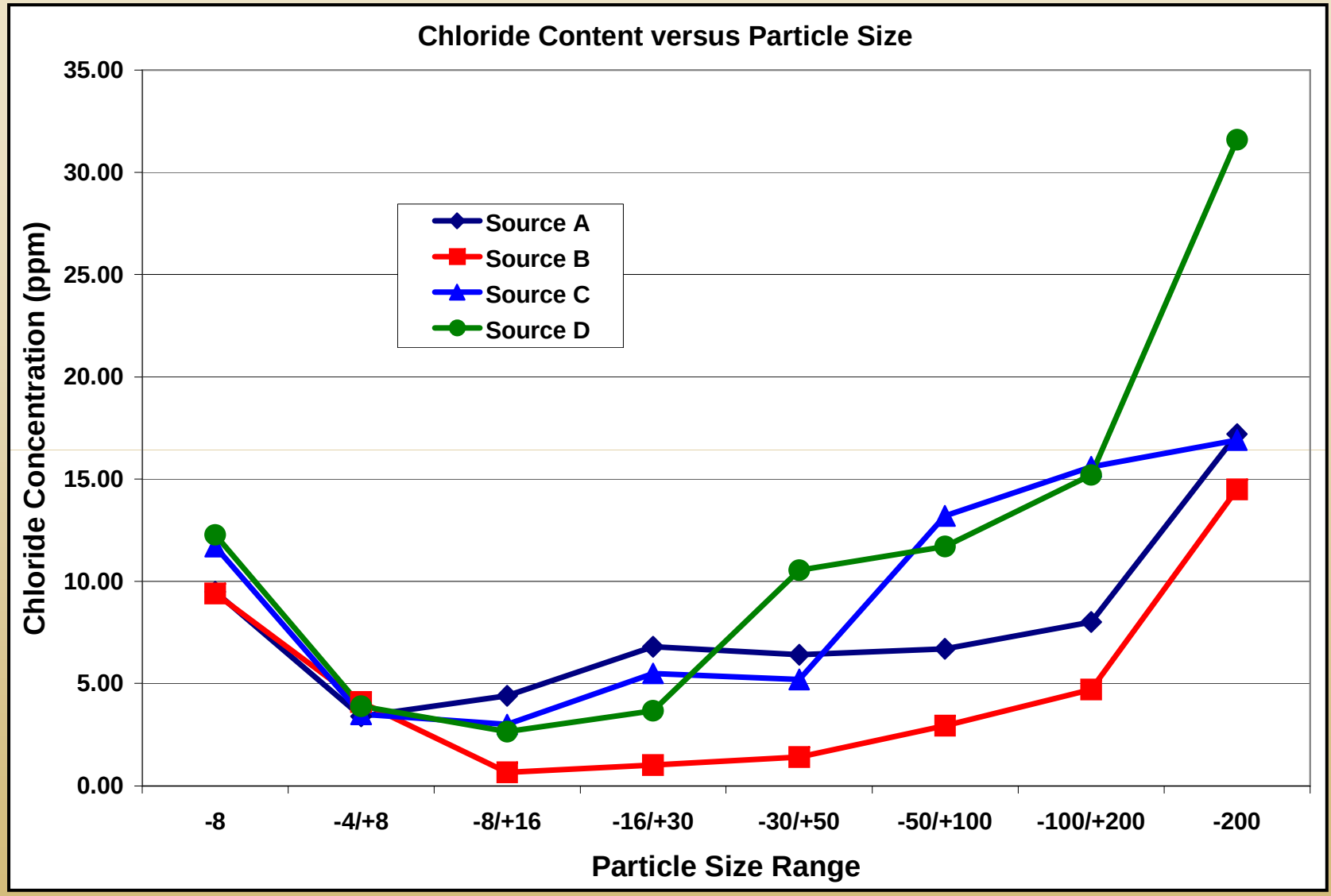


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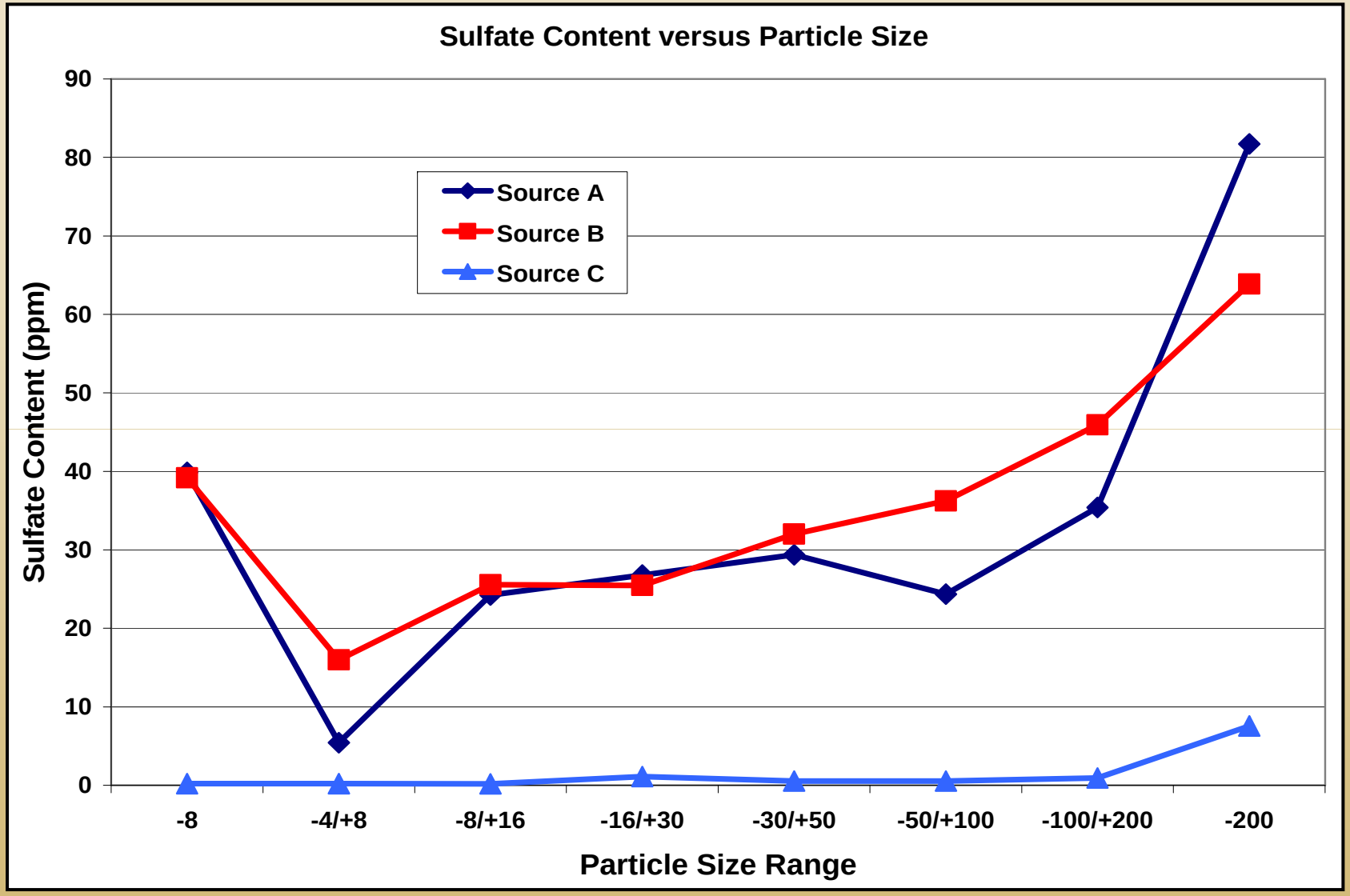


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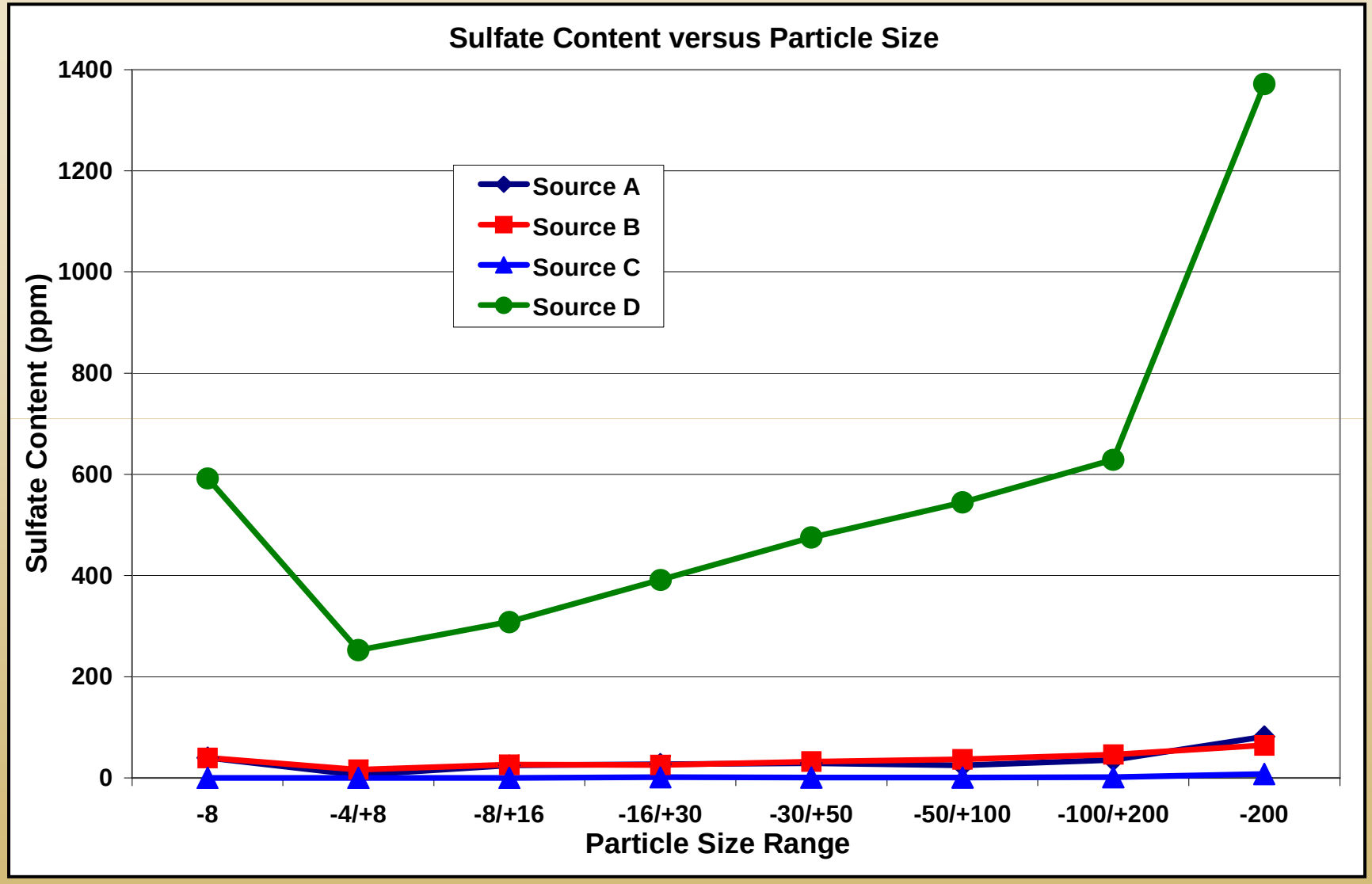
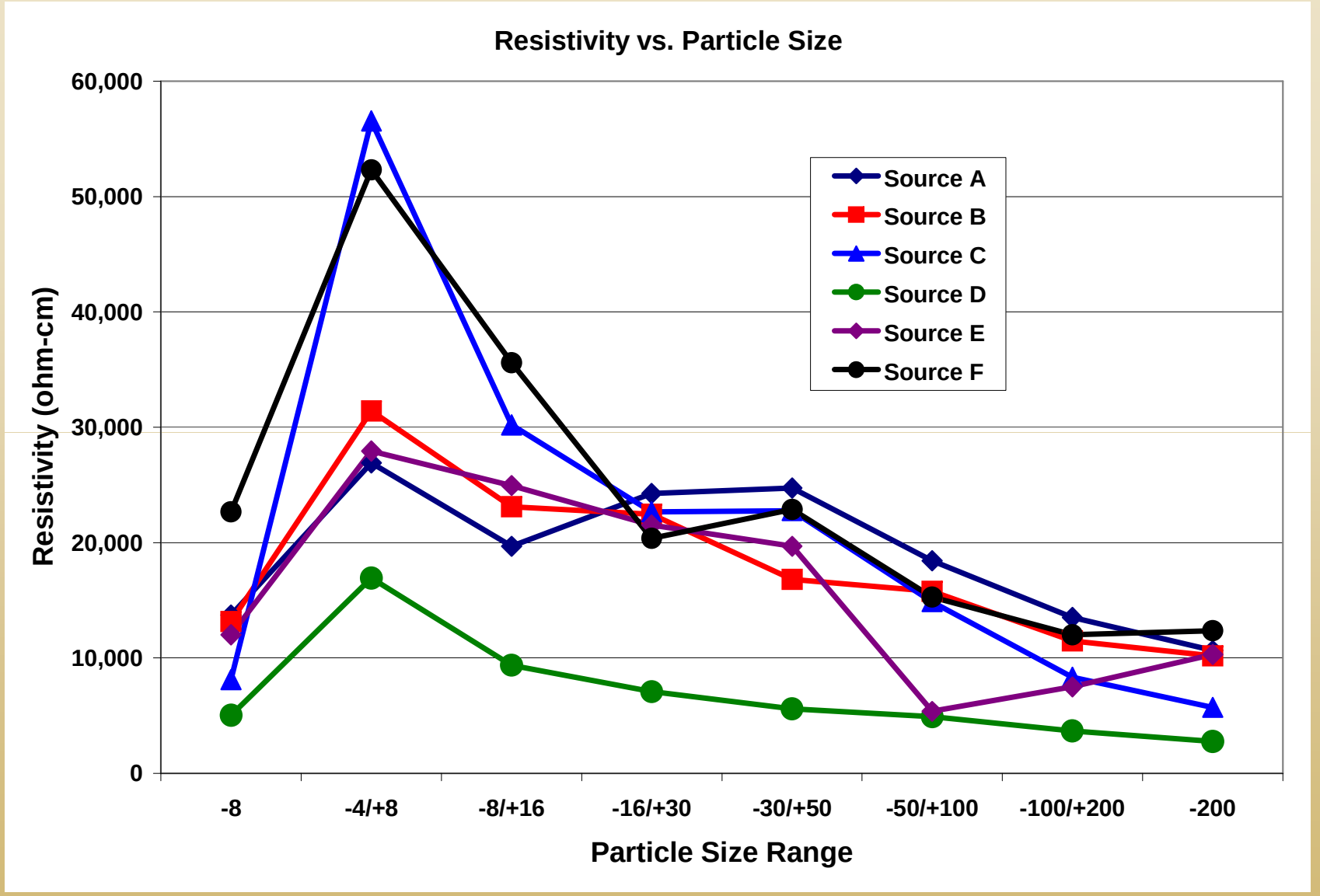

Sulfate Content versus Particle Size
Sulfate Content (ppm)
1400
1200
1000
800
600
400
200
0
Source A
Source B
Source C
Source D
-8
-4/+8
-8/+16
-16/+30
-30/+50
-50/+100
-100/+200
-200
Particle Size Range


Resistivity vs. Particle Size
60,000
50,000
40,000
30,000
20,000
10,000
0
Resistivity (ohm-cm)
Source A
Source B
Source C
Source D
Source E
Source F
-8
-4/+8
-8/+16
-16/+30
-30/+50
-50/+100
-100/+200
-200
Particle Size Range

# Results - Conclusion

1) Resistivity, and Chloride and Sulfate contents impacted by particle size
2) pH not affected by particle size
3) Testing material in a manner not consistent with how placed, results in misrepresentation in material properties

# Recommendation

1) Prepare sample in manner consistent with material use
2) Model material as close to application conditions as possible
3) MSE Wall Backfill – use coarse grain substitution
4) Substitute plus #8 material fraction with equal percent by weight of minus #8 to plus #16 material

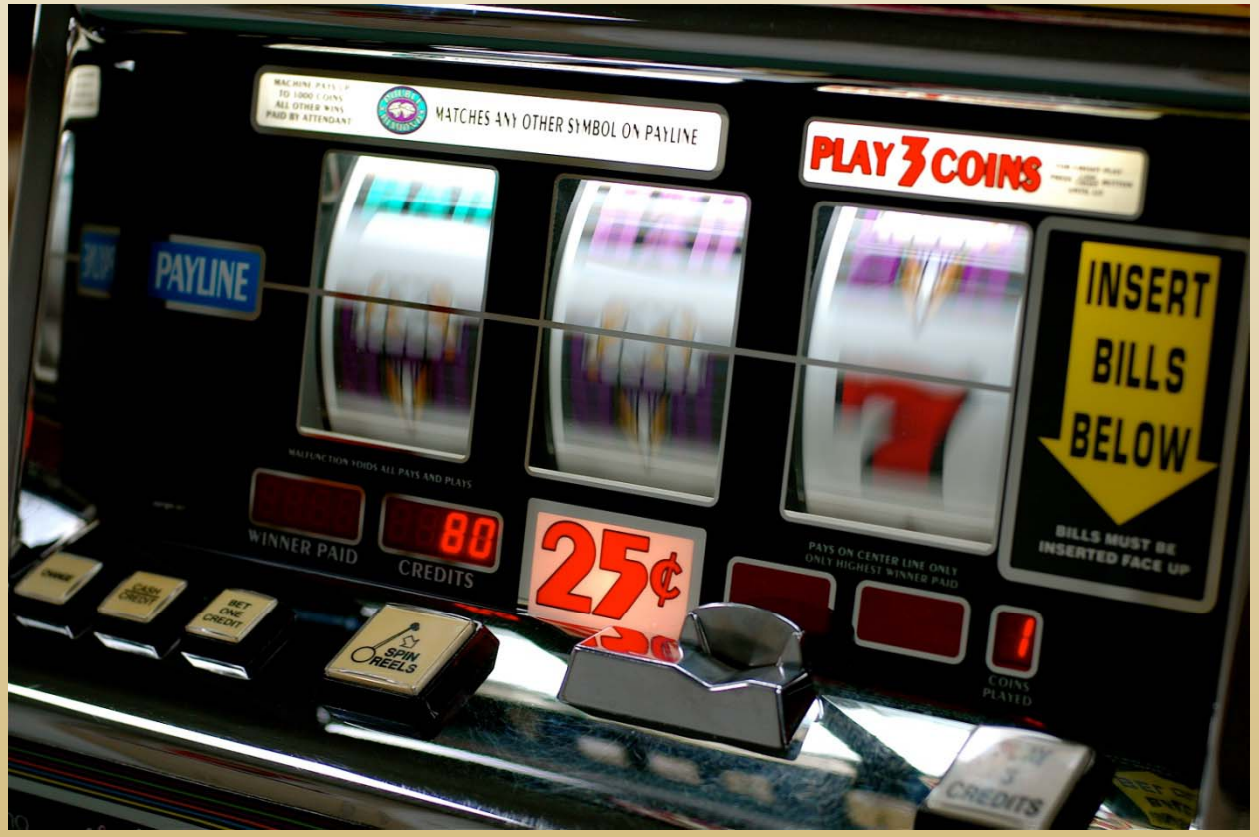
# Some Early Results

| Material | #57 Coarse Aggregate | |
|---|---|---|
| Parameter | Normal Minus #10 Sample | Coarse Particle Substitution |
| Resistivity (ohm-cm) | 16,960 | 22,730 |
| Friction Angle (degrees) | 35 | 41 |

## General Observation – All Materials

1) Testing material in a manner not consistent with how placed, can result in misrepresentation in material properties or performance expectations
2) When testing, model material and test as close to application conditions as possible

# Save gambling for the casino;




# Not your test samples!

Thank You!

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