Manual for Emulsion-Based Chip Seals for Pavement Preservation

by

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Northeast Pavement Preservation Partnership
Portsmouth, NH
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Colorado State University
Knowledge to Go Places

Thanks To:

National Cooperative Highway Research Program

Project 14-17 “Manual for Emulsion-Based Chip Seals for Pavement Preservation”

Colorado DOT,
Washington DOT,
FHWA Federal Lands,
A-1 Chip Seal

Objective

WRITE A MANUAL THAT TAKES THE GUESS WORK OUT OF CHIP SEAL DESIGN AND CONSTRUCTION

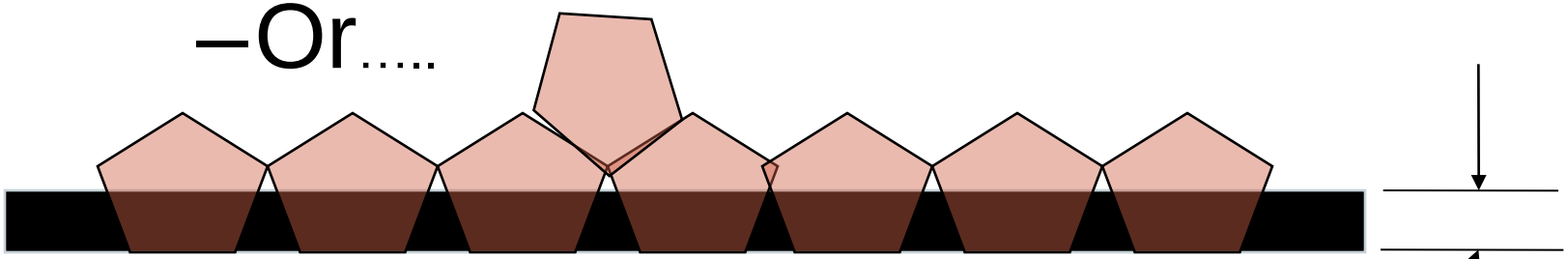
Approach

- Much of What is Necessary is Known (85% ?)
  - Capture This and Write it Down
- Quantify the Rest and Write it Down

Quantities

- Spread Rate
  - One Stone Thick

–Or…..



- Embedment
  - 40-50%

Getting Quantities Right

- Follow A Design Method
  - South Africa/Australia/New Zealand/Hanson
  - Asphalt Institute/McLeod/Hanson
    - Asphalt Rates Too Low, Aggregate Rates Too High
  - Texas/Kearby/Gallaway
    - Asphalt Rates Too Low, Aggregate Rates Too Low

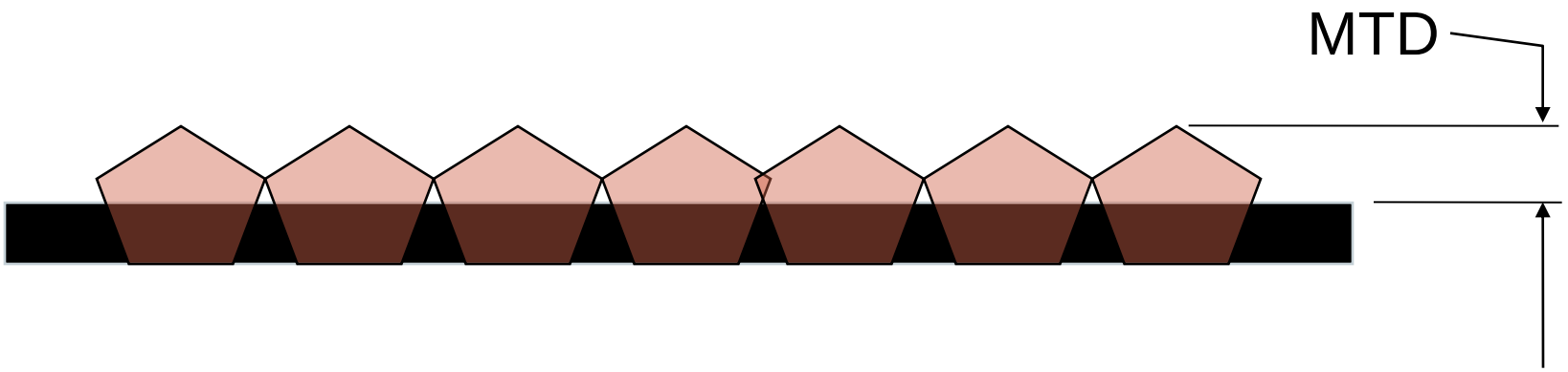
Replacing ‘Art’ with Science

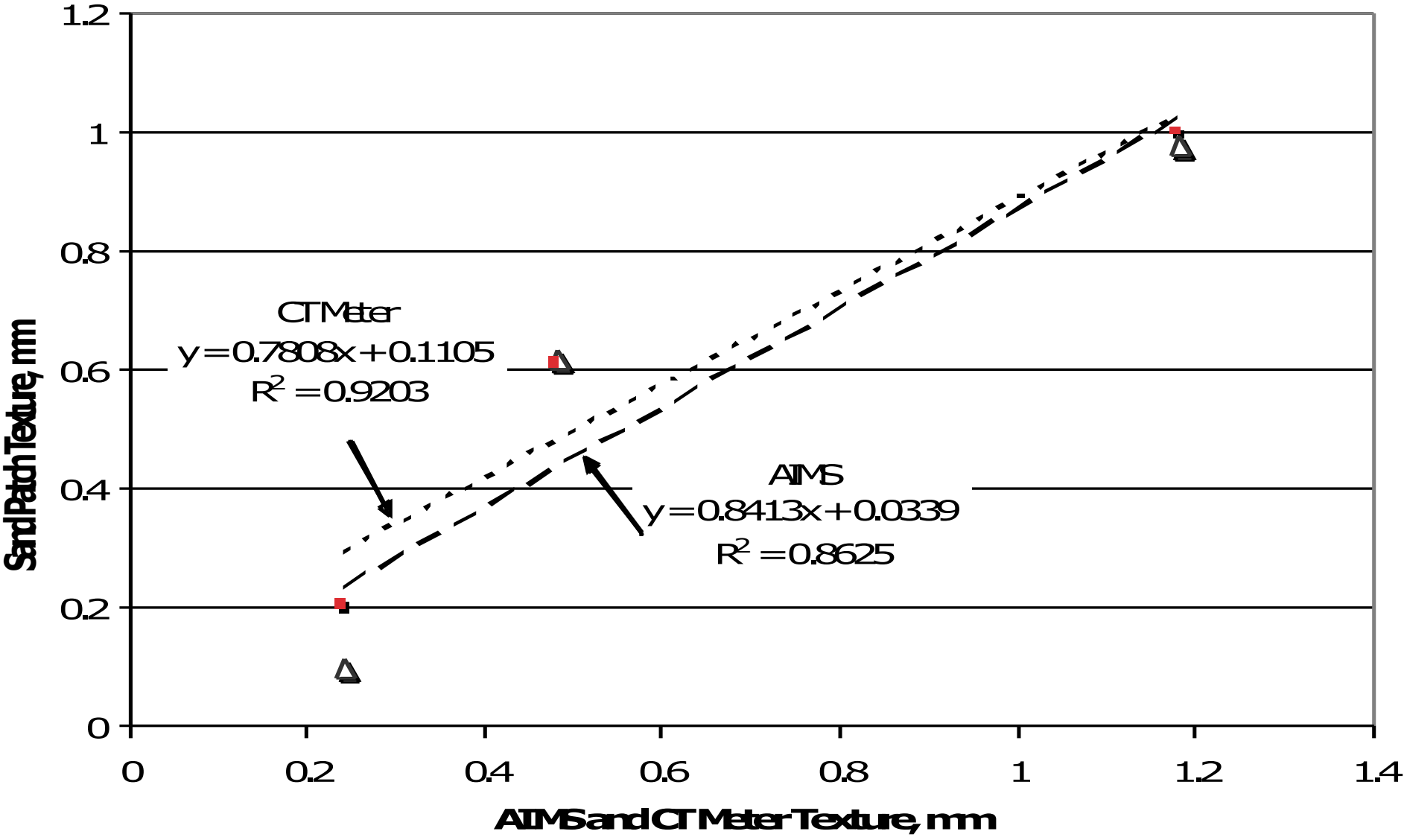
- Turning Traffic Loose/Sweeping
- Surface Texture
- Surface Resistance to Chip Embedment
- Emulsion Correct on Job?
- Embedment Depth

NCHRP 14-17 Contribution

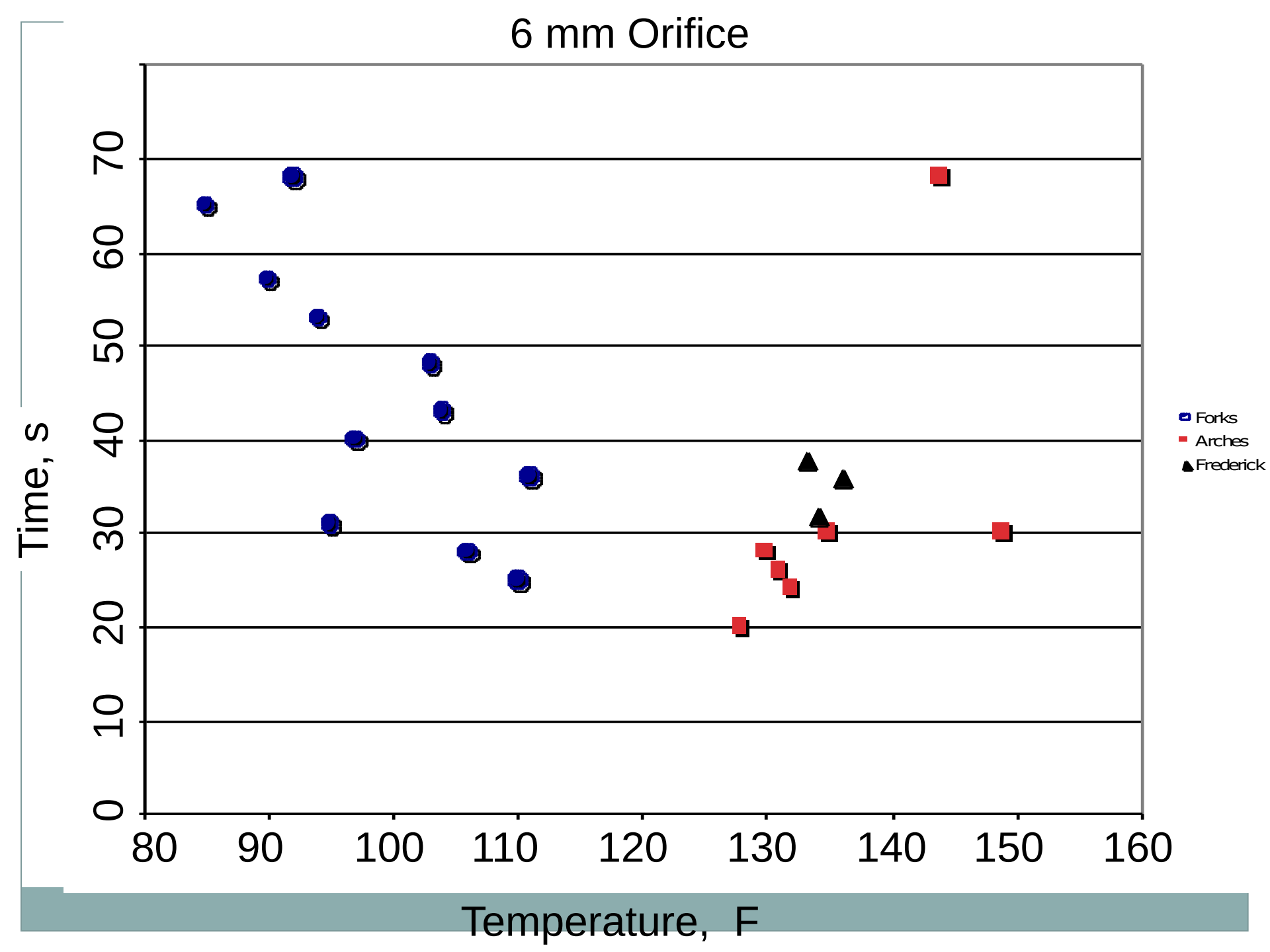
Surface Texture

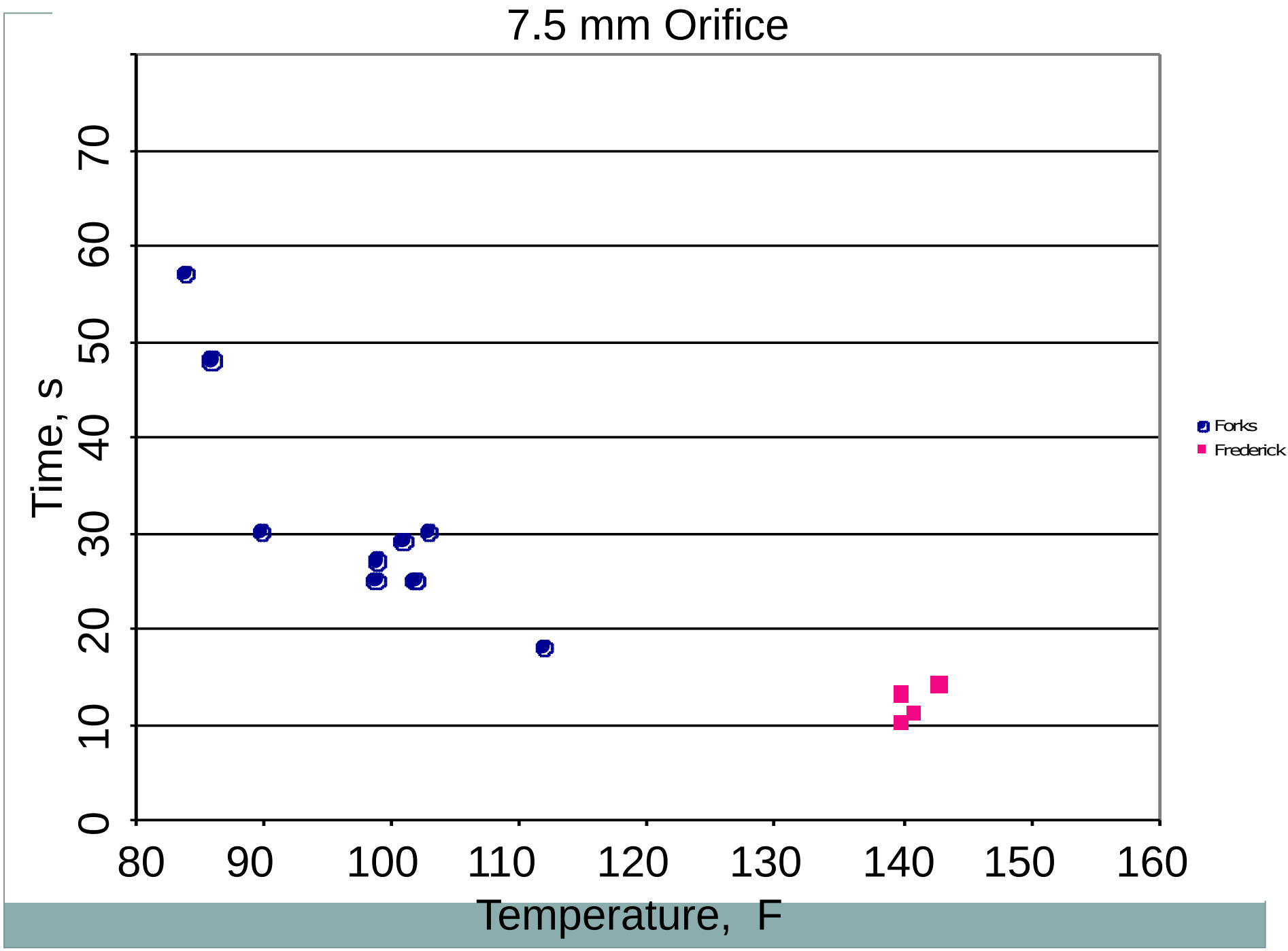
Mean Texture Depth

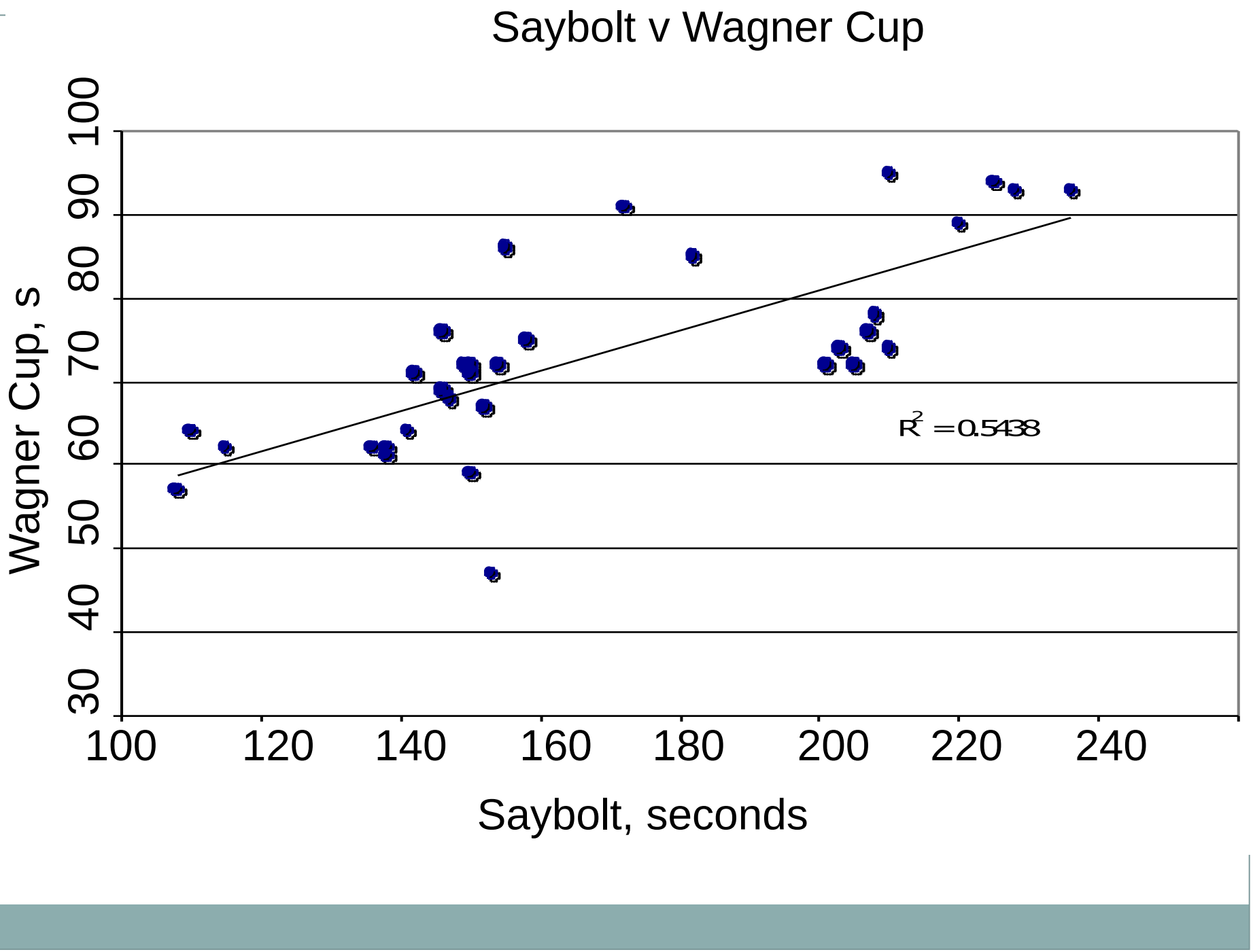



1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Sand Patch Texture, mm
AIMS and CT Meter Texture, mm
CT Meter
y = 0.7808x + 0.1105
R2 = 0.9203
AIMS
y = 0.8413x + 0.0339
R2 = 0.8625

Viscosity in Field


6 mm Orifice
Time, s
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Temperature, F
Forks
Arches
Frederick


7.5 mm Orifice
Time, s
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Temperature, F
Forks
Frederick

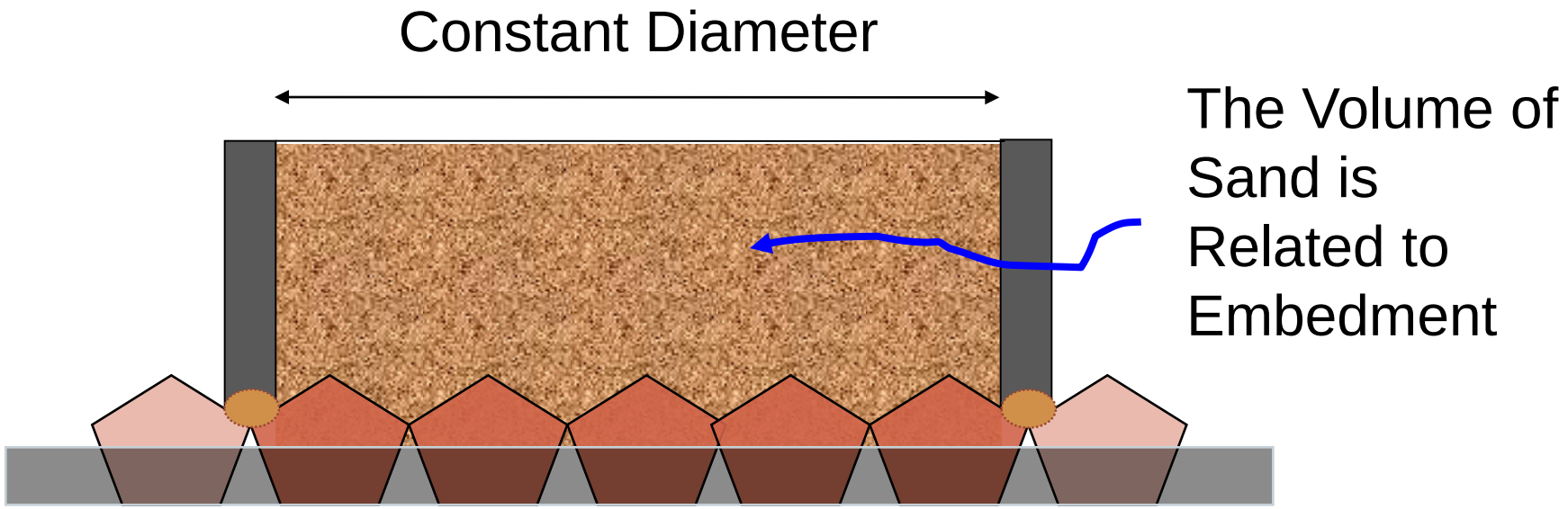

Saybolt v Wagner Cup
Wagner Cup, s
100
90
80
70
60
50
40
30
100
120
140
160
180
200
220
240
Saybolt, seconds
R² = 0.5438

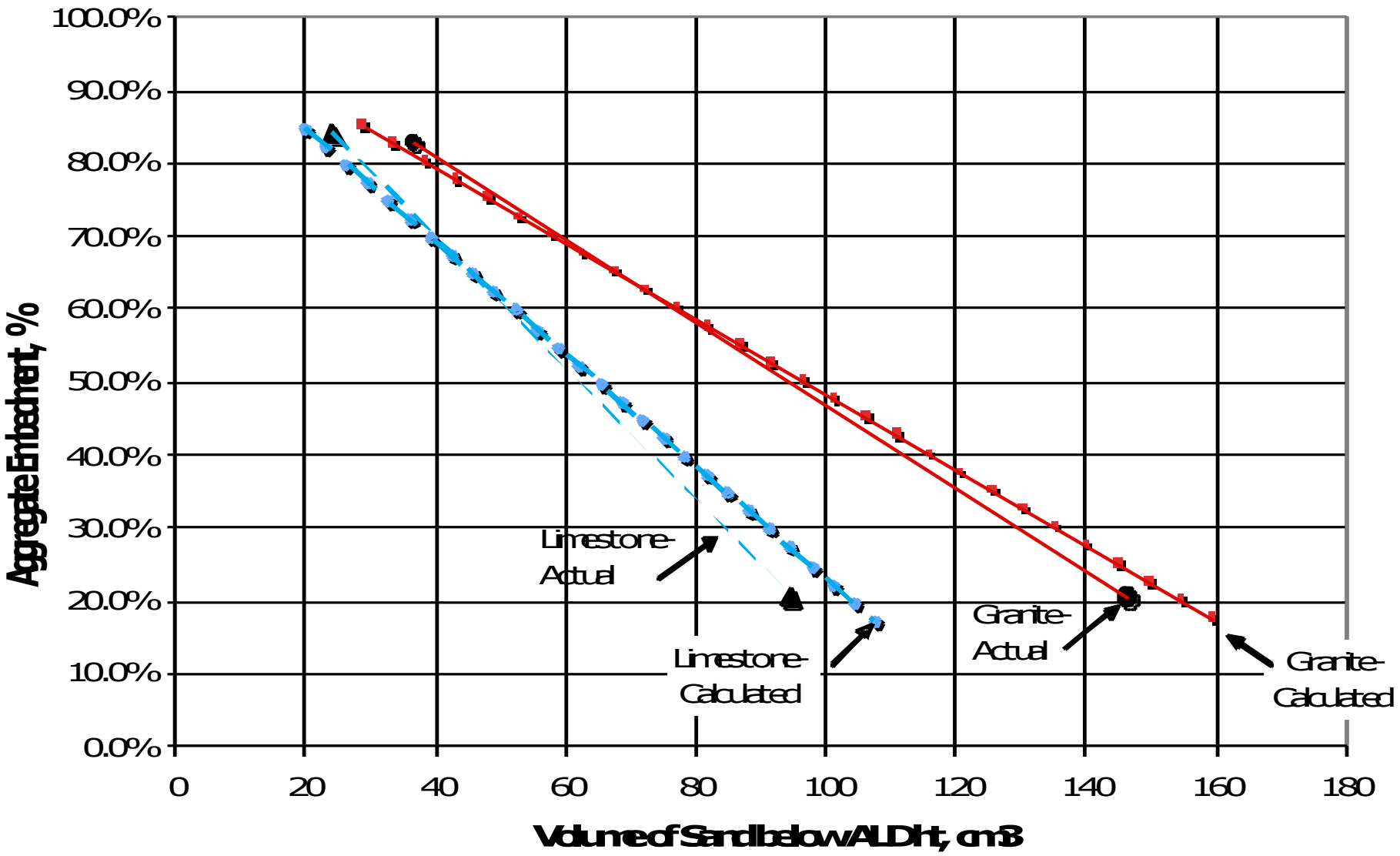
Resistance to Chip Embedment


mm
in
TITAN
STAINLESS
HARDENED

Estimating Embedment Depth

Embedment Depth in Field




100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0
20
40
60
80
100
120
140
160
180
Aggregate Embedment, %
Volume of Sand below ALD ht, cm3
Limestone-Actual
Limestone-Calculated
Granite-Actual
Granite-Calculated

Can Time to Brooming or Traffic be Predicted?

- If So….
  - Windshields Could be Saved,
  - More Chip Seals Would be Built,
  - Deficit Eliminated,
  - World Peace


Chips at One-Stone Thickness
"Pin-Art" Holds Chips
The 'Grabber'
Template =
40% Embedment
A Pneumatic Roller
Would be an
Improvement


NCHRP 14-17
“Broom Simulator”

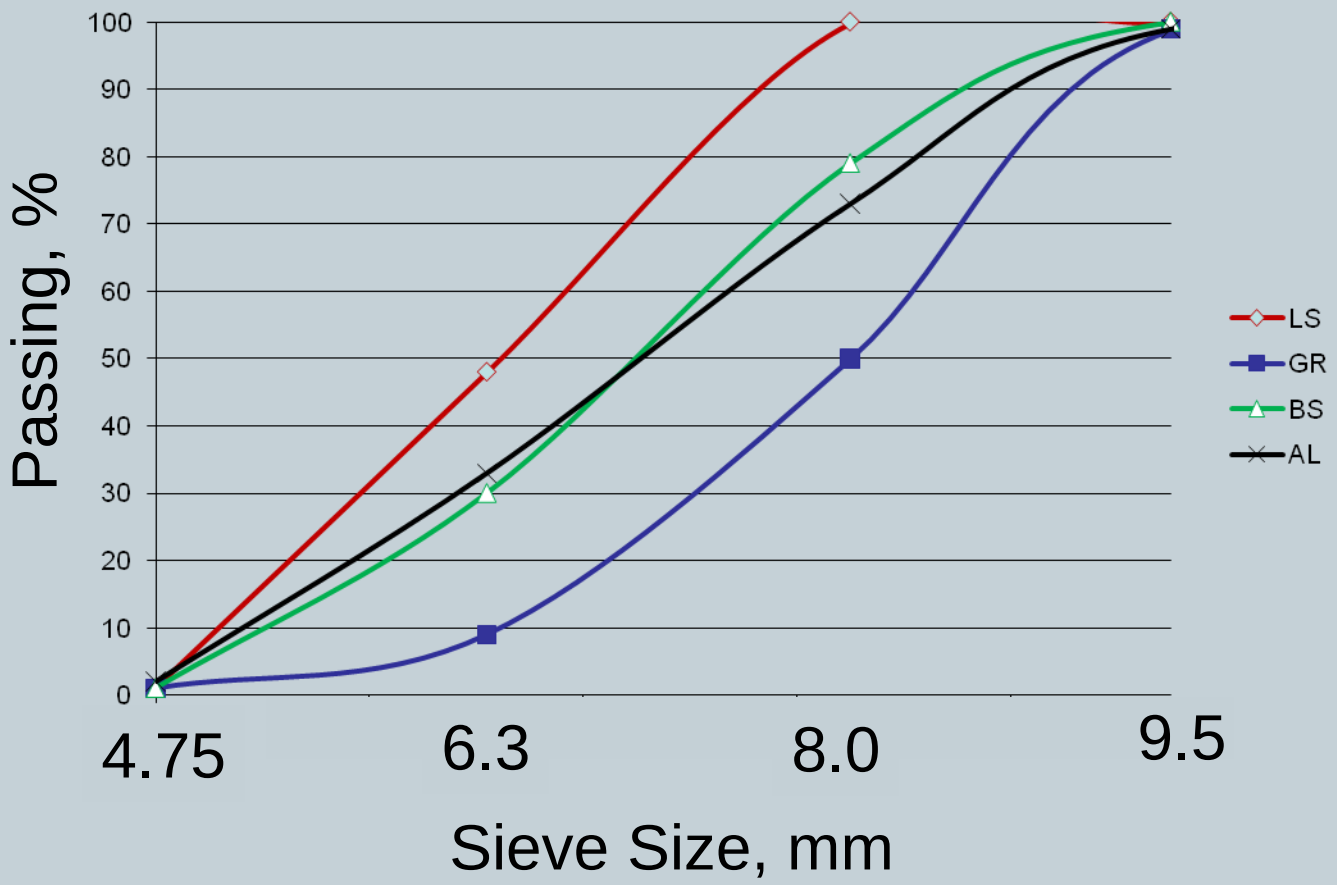
Test the Test

- AGGREGATES:
  - Basalt, Alluvial, Granite, Limestone
- EMULSIONS:
  - RS-2, RS-2P, CRS-2, CRS-2P
- EMULSION CURE:
  - 40%, 80%
- AGGREGATE MOISTURE:
  - Dry, SSD

Full Factorial Experiment Design

- $Y_{iklm} = \mu + A_i + W_k + M_l + AW_{ik} + AM_{il} + WM_{kl} + AWM_{ikl} + e_{iklm}$
-
- Where,
- Y_{ijklm} = Chip Loss, %
- μ = mean loss, %
- A_i = effect of aggregate i on mean
- W_k = effect of water removed (40, 80%) k on mean
- M_l = effect of aggregate moisture l on mean (dry,SSD)
- AW_{ik}, etc. = effect of interactions on mean
- e_{iklm} = random error

Aggregates


Passing, %
100
90
80
70
60
50
40
30
20
10
0
4.75
6.3
8.0
9.5
Sieve Size, mm
LS
GR
BS
AL

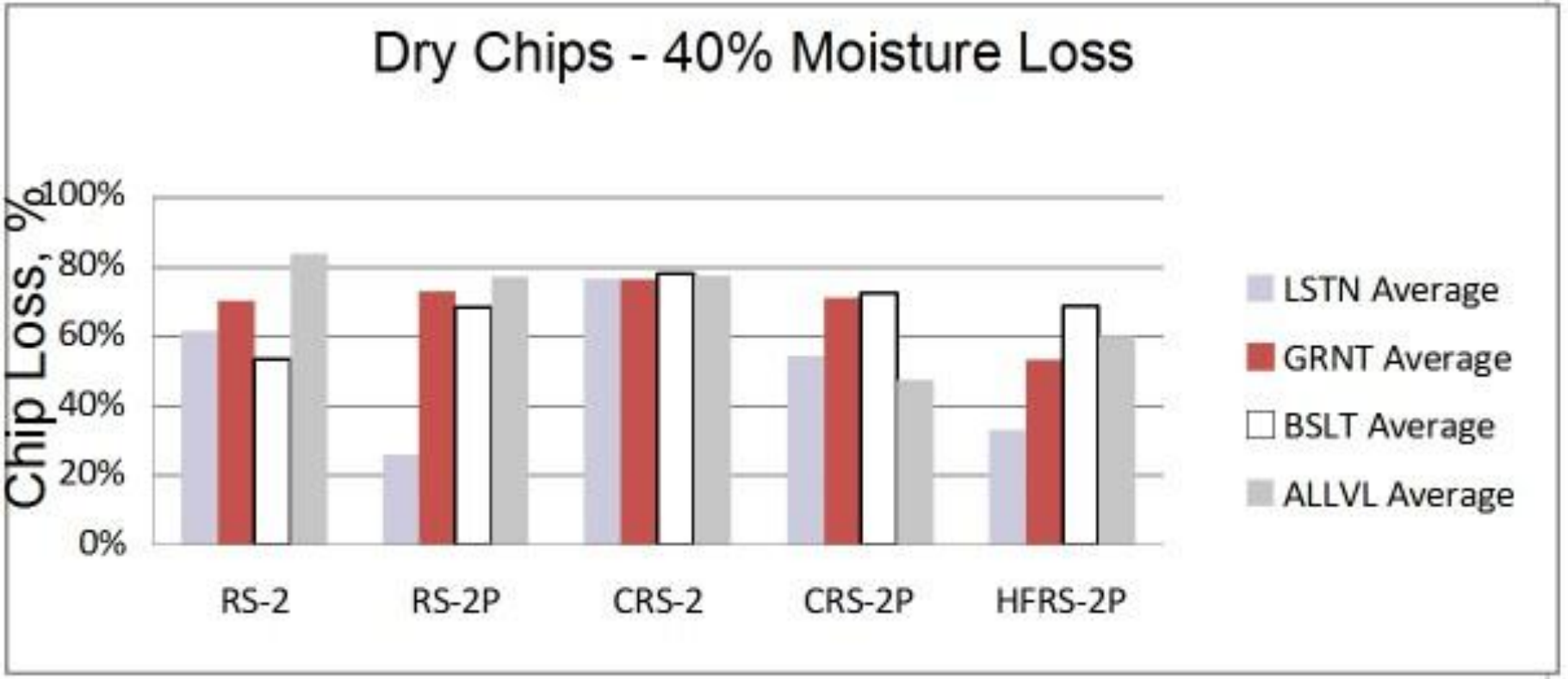
Aggregates

	LS	GR	BS	AL
BSG	2.615	2.612	2.773	2.566
Median Size, in	0.252	0.315	0.277	0.277
ALD, in	0.170	0.265	0.218	0.222
Design Coverage, psy	16.48	26.11	22.95	21.73

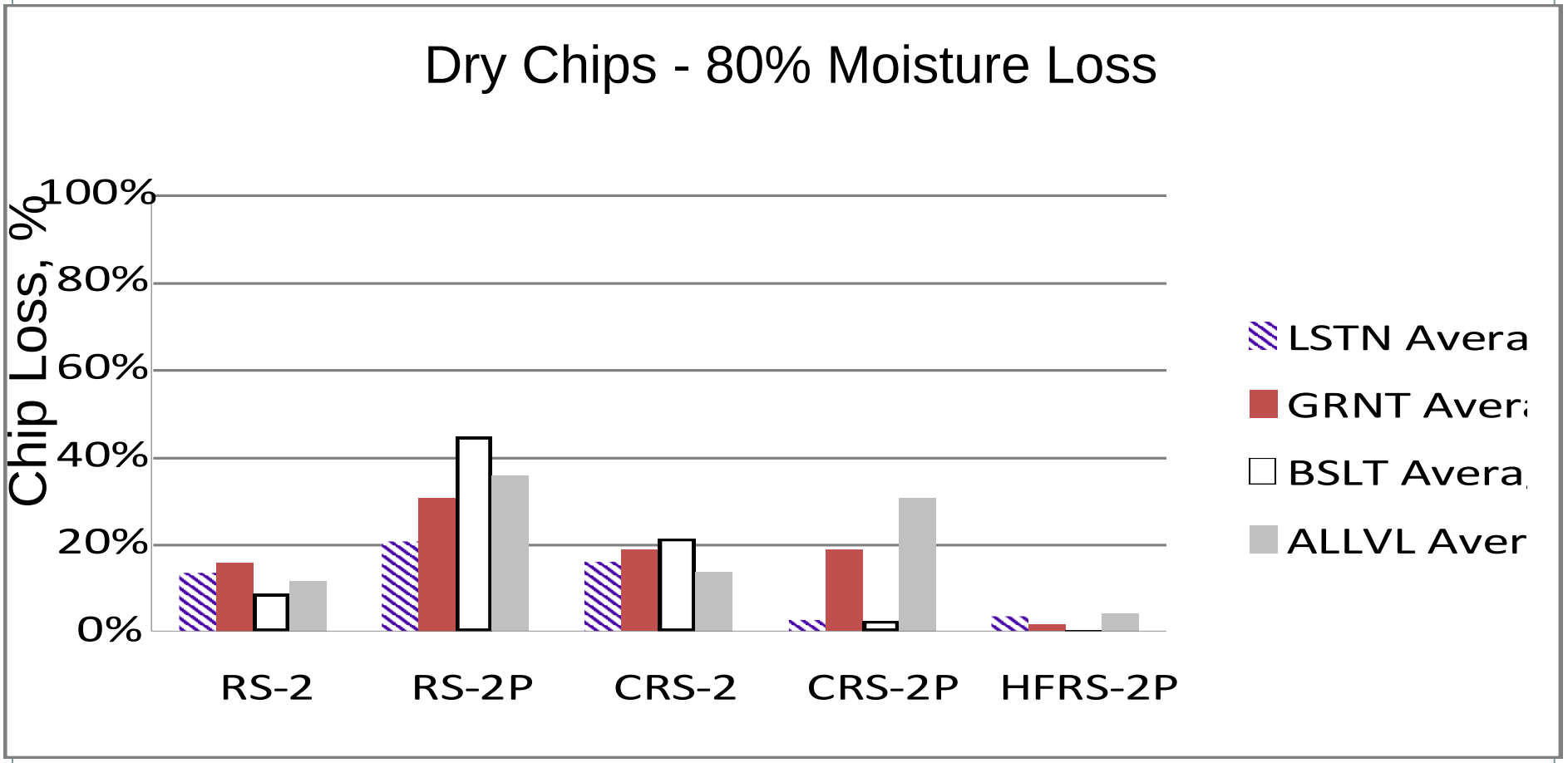
Emulsions

	RS-2P	RS-2	CRS-2	CRS-2P	HFRS-2P
SF, 50C	108	96	78	119	132
Residue, %	65	68	68	68	65
Pen, 25C, 100g	115	95	125	85	115
Ductility, 25C	100+	100+	55	65	60

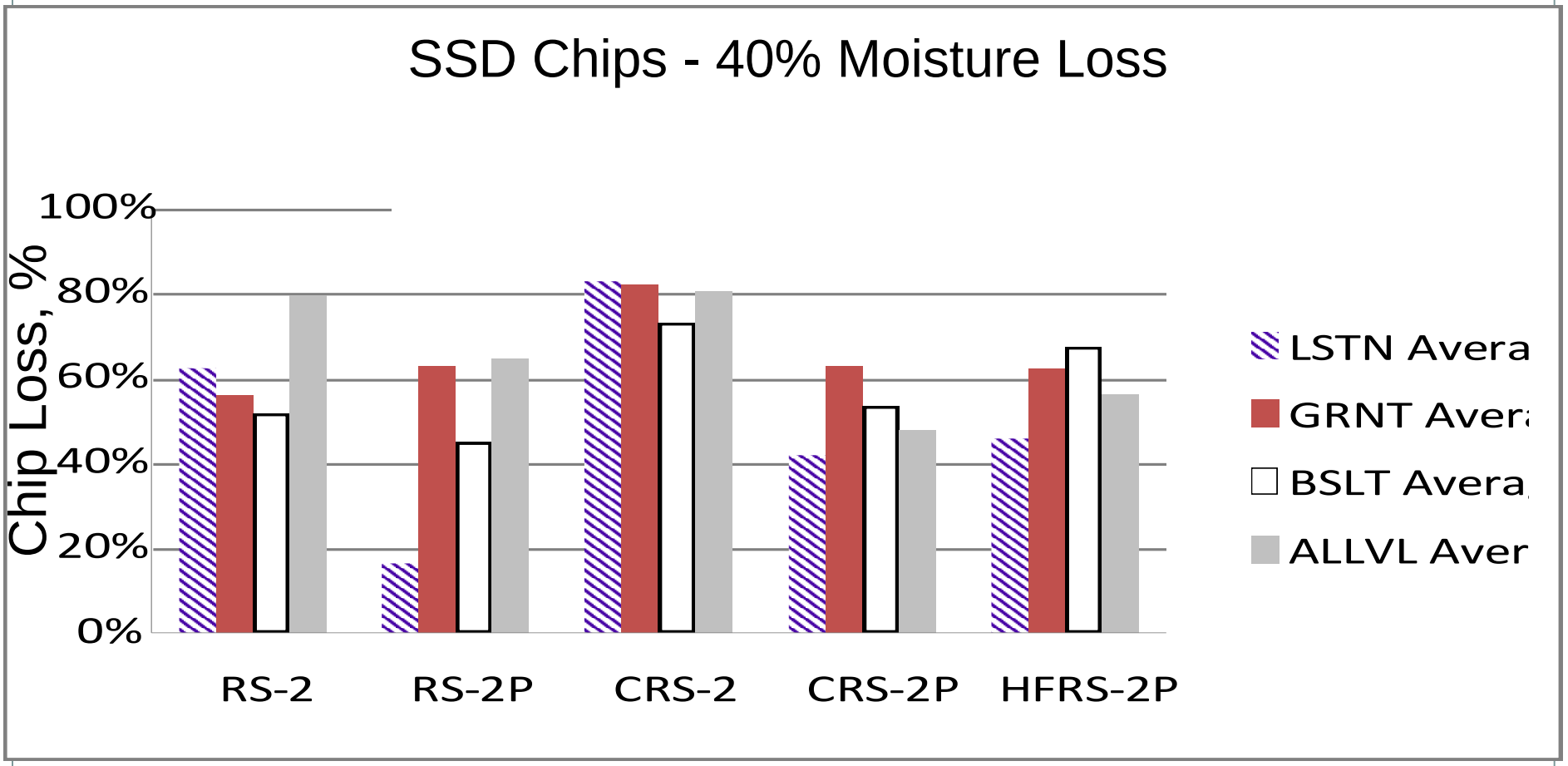
Results


Dry Chips - 40% Moisture Loss
Chip Loss, %
100%
80%
60%
40%
20%
0%
RS-2
RS-2P
CRS-2
CRS-2P
HFRS-2P
LSTN Average
GRNT Average
BSLT Average
ALLVL Average

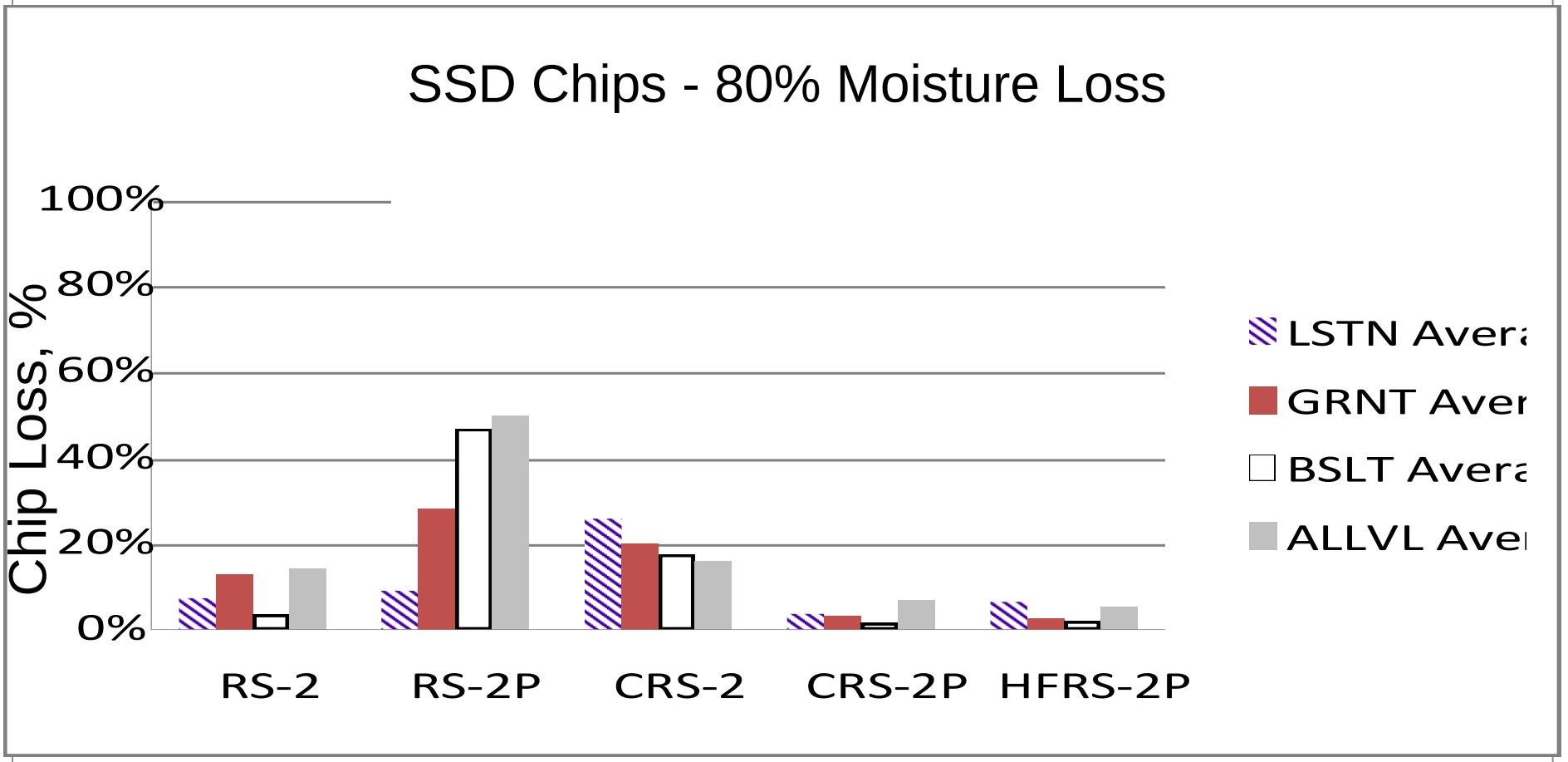
Results


Dry Chips - 80% Moisture Loss
Chip Loss, %
100%
80%
60%
40%
20%
0%
RS-2
RS-2P
CRS-2
CRS-2P
HFRS-2P
LSTN Avera
GRNT Avera
BSLT Avera
ALLVL Aver

Results


SSD Chips - 40% Moisture Loss
Chip Loss, %
100%
80%
60%
40%
20%
0%
RS-2
RS-2P
CRS-2
CRS-2P
HFRS-2P
LSTN Avera
GRNT Avera
BSLT Avera
ALLVL Aver

Results

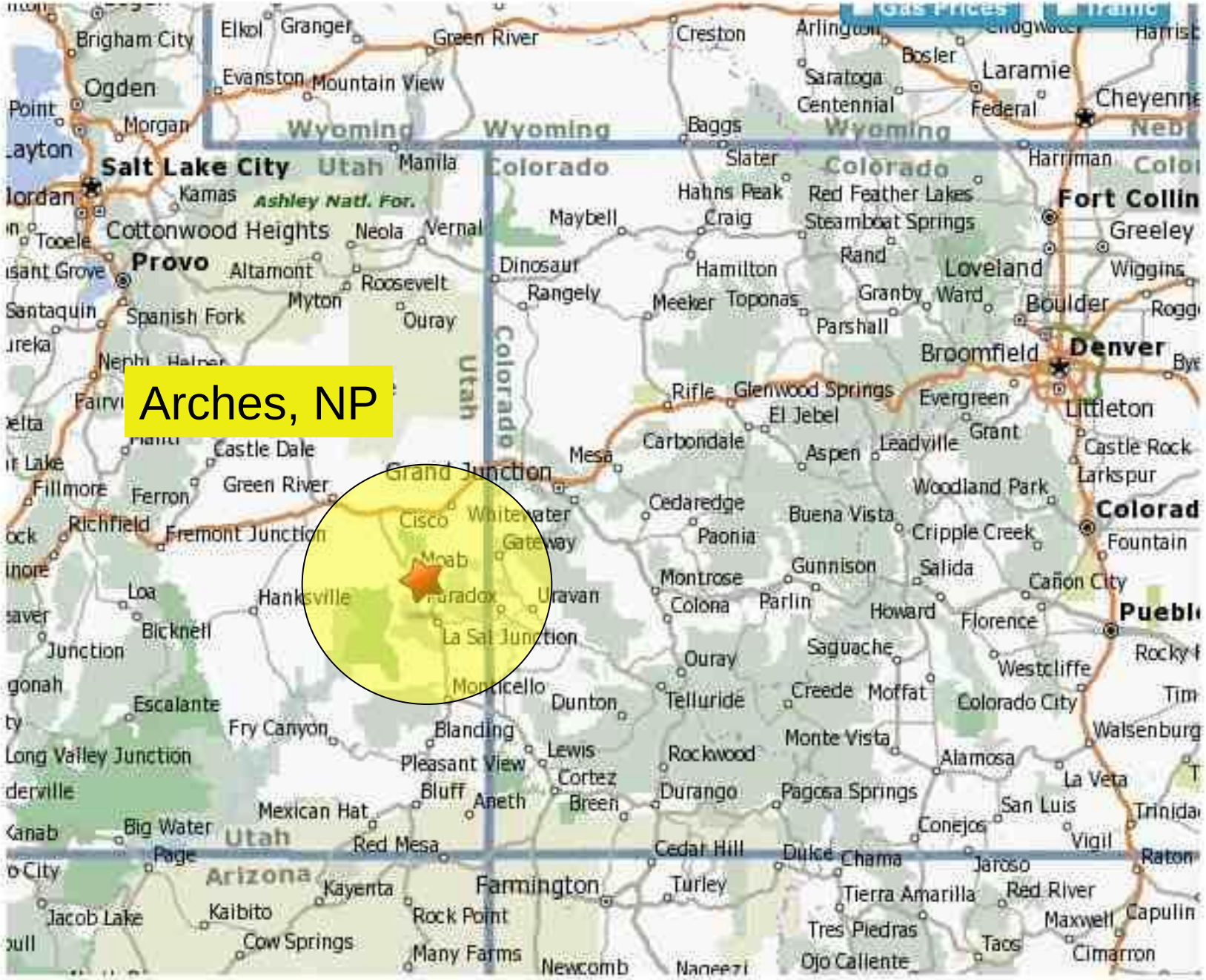

SSD Chips - 80% Moisture Loss
Chip Loss, %
100%
80%
60%
40%
20%
0%
RS-2
RS-2P
CRS-2
CRS-2P
HFRS-2P
LSTN Avera
GRNT Aver
BSLT Avera
ALLVL Aver

ANOVA

	Alpha Level for Significant Differences				
Variable Tested	RS2	RS2P	CR-8	CR-8P	HRS2P
aggregate	<0.0001	<0.0001	0.3887	0.0049	<0.0001
moisture	0.0169	0.0220	0.1597	0.0003	0.0335
cure	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
agg x moist	0.2468	0.3618	0.0994	0.7574	0.5837
agg x cure	0.0001	0.0020	0.3927	0.0005	0.0032
moist x cure	0.5425	0.0136	1.0000	0.9546	0.6490
agg x moist x cure	0.1064	0.2088	0.8805	0.0114	0.2366

So, the Lab Test May Be Promising.

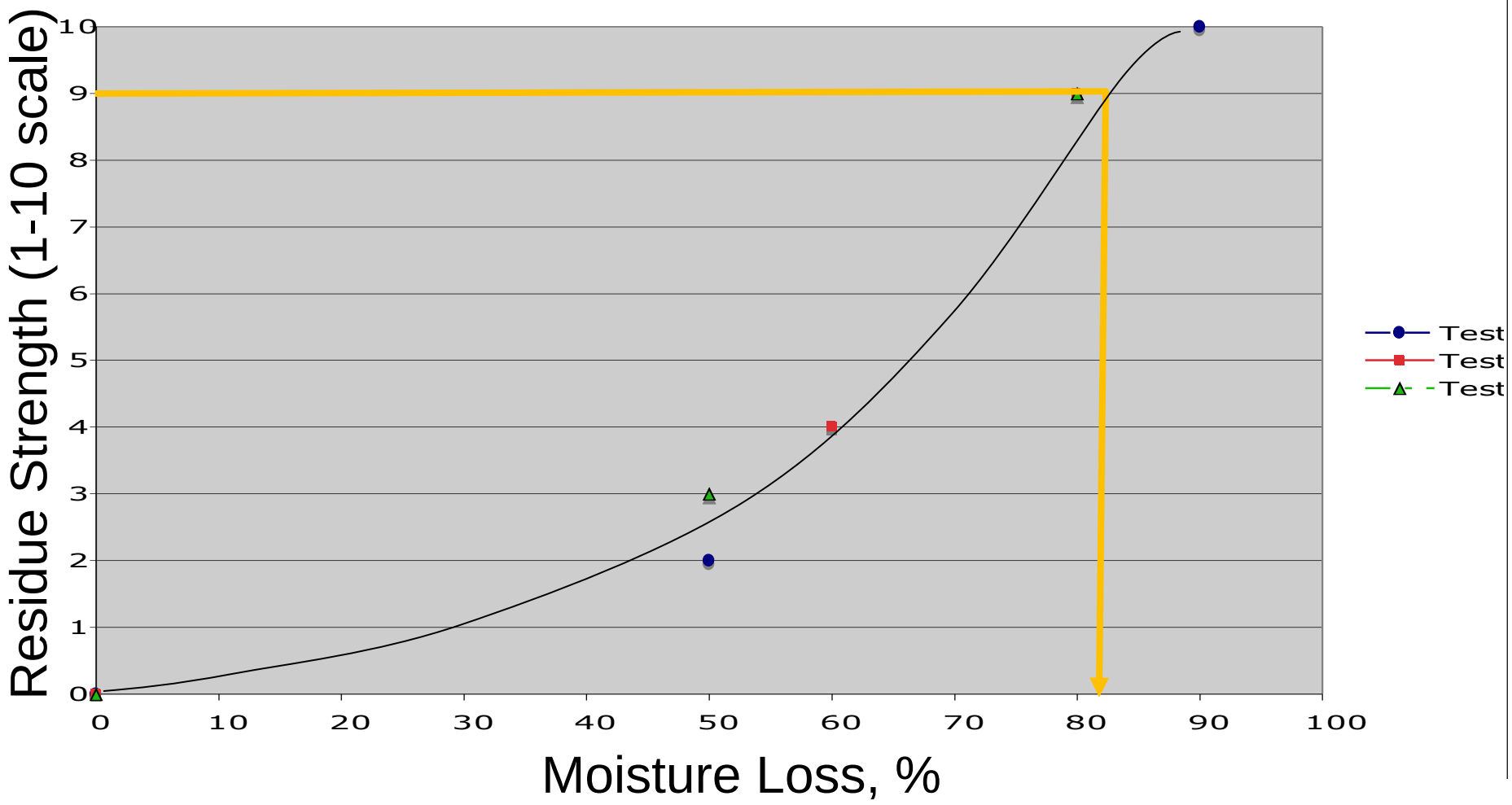
How Does It Relate to the Field?


Arches, NP
Brigham City
Elkol
Granger
Green River
Creston
Arlington
Bosler
Laramie
Saratoga
Centennial
Federal
Cheyenne
Ogden
Evanston
Mountain View
Point
Morgan
Wyoming
Wyoming
Wyoming
Baggs
Layton
Salt Lake City
Utah
Manila
Colorado
Slater
Colorado
Harriman
Jordan
Kamas
Ashley Natl. For.
Hahns Peak
Red Feather Lakes
Fort Collin
Cottonwood Heights
Neola
Vernal
Maybell
Craig
Steamboat Springs
Greeley
Tooele
Provo
Altamont
Roosevelt
Dinosaur
Hamilton
Rand
Loveland
Wiggins
Santaquin
Myton
Rangely
Meeker
Toponas
Granby
Ward
Boulder
Spanish Fork
Ouray
Parshall
Broomfield
Denver
Nephi
Utah
Colorado
Rifle
Glenwood Springs
Evergreen
Littleton
El Jebel
Carbondale
Grant
Castle Dale
Mesa
Aspen
Leadville
Castle Rock
Fillmore
Ferron
Green River
Grand Junction
Woodland Park
Larkspur
Richfield
Fremont Junction
Cisco
Whitewater
Cedaredge
Buena Vista
Colorad
Gateway
Paonia
Cripple Creek
Fountain
Moab
Montrose
Gunnison
Salida
Loa
Hanksville
Uravan
Colona
Parlin
Howard
Florence
Cañon City
Bicknell
La Sal Junction
Saguache
Junction
Ouray
Westcliffe
Escalante
Monticello
Dunton
Telluride
Creede
Moffat
Colorado City
Fry Canyon
Blanding
Monte Vista
Long Valley Junction
Pleasant View
Lewis
Rockwood
Alamosa
Cortez
La Veta
Bluff
Aneth
Breen
Durango
Pagosa Springs
San Luis
Mexican Hat
Conejos
Big Water
Utah
Red Mesa
Cedar Hill
Dulce
Chama
Vigil
Page
Arizona
Jaroso
Kayenta
Farmington
Turley
Tierra Amarilla
Red River
Jacob Lake
Kaibito
Rock Point
Tres Piedras
Maxwell
Capulin
Cow Springs
Many Farms
Taos
Cimarron
Newcomb
Ojo Caliente

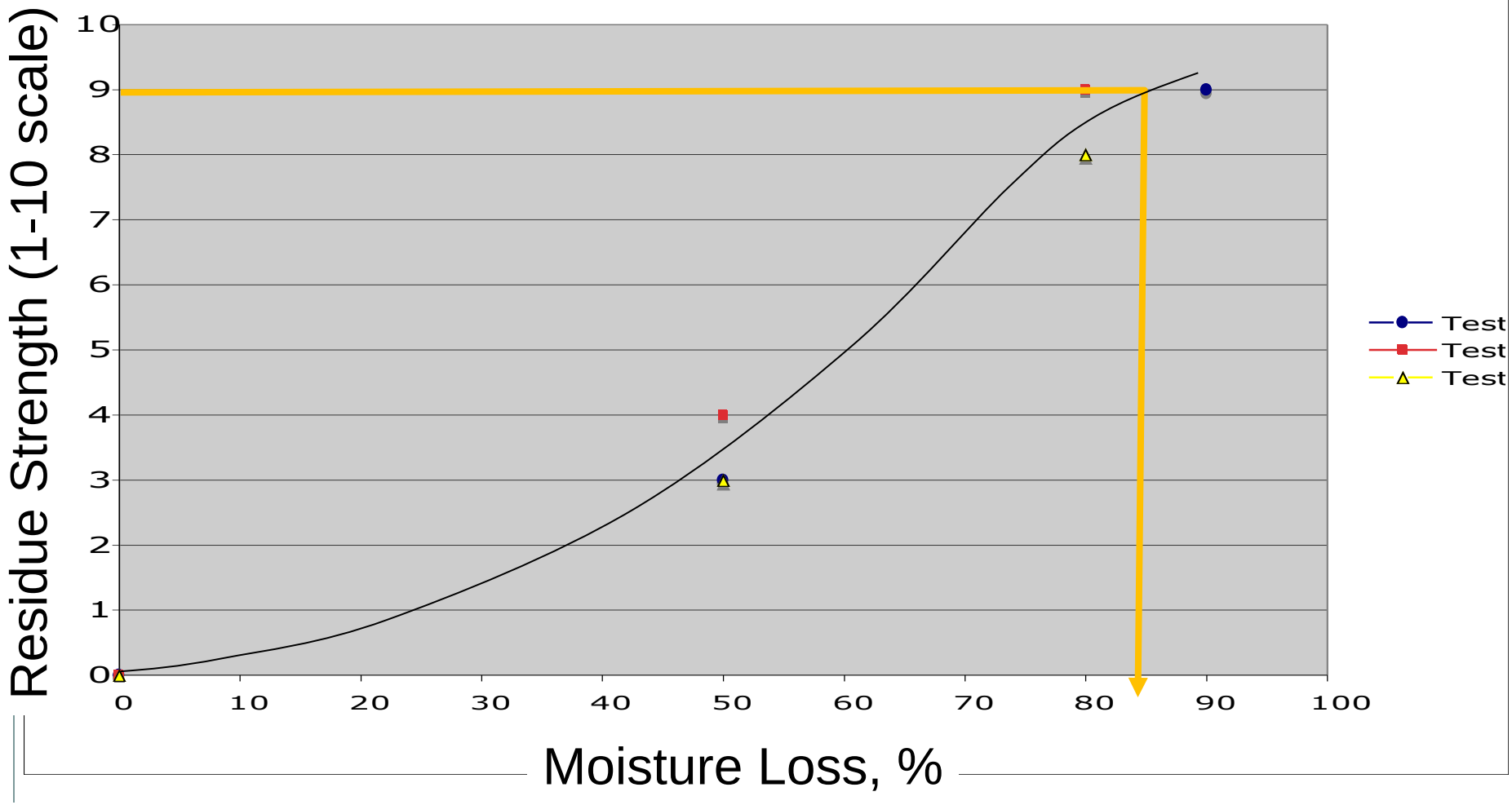

Frederick, CO
Ute Hwy
Hygiene
Longmont
Main St
66
7
66
30
85
24
19
25
13
Firestone
119
287
1
Boulder
Weld
Niwot
Mineral Rd
52
14
52
Fort Lupton
52
52
38
N Foothills Hwy
157
Erie
6
85
Wattenberg
37
76
Boulder
Arapahoe Rd
Lochbuie
93
42
Lafayette
7
Weld
Adams
Brighton
Louisville
E470
Superior
Eldorado Springs
Broomfield
Eastlake
Henderson
Plainview
Northglenn
Thornton
2
Denver
Int'l
Airport
Westminster
Dupont
Pena Blvd
36
270
Commerce City
Arvada
Montbello
Adams
Denver
Wheat Ridge
Golden
Edgewater
Applewood
Denver
Aurora
Watkins
36
70
70
Lakewood
Glendale


Forks, WA
Bamfield
Lake Cowichan
North Cowichan
Ferndale
Bellingham
Marietta
Geneva
North Saanich
Sidney
Waldron
Blanchard
Wickersham
Port Renfrew
Mill Bay
Central Saanich
Orcas
Anacortes
Sedro Woolley
Victoria
Lopez
River Jordan
Colwood
Sooke
Mount Vernon
Metchosin
Oak Harbor
McMurray
Oso
Clallam Bay
San De Fuca
Coupeville
Arlington
Joyce
Port Angeles
Port Townsend
Smokey Point
Sappho
Sequim
Port Hadlock
Everett
Forks
Port Ludlow
Mukilteo
Snohomish
Olympic Natl. Park
Quilcene
Hansville
Edmonds
Monroe
Gold
Brinnon
Mountlake Terrace
Shoreline
Seattle
Kalaloch
Bremerton
Queets
Amanda Park
Quinault
Lilliwaup
Eldon
Belfair
Burien
Renton
Kent
Taholah
Neilton
Grisdale
Tahuya
Seatac
Gig Harbor
Black Diamond
Moclips
Humptulips
Matlock
University Place
Tacoma
Shelton
Parkland
Puyallup
Copalis Beach
Carlisle
McCleary
Olympia
Elk Plain
Carbonado
Ocean Shores
Hoquiam
Montesano
Roy
Lacey
Tumwater
Westport
Cosmopolis
Yelm
Eatonville
Markham
Littlerock
Grayland
Brooklyn
Oakville
La Grande
Centralia
Bay Center
South Bend
Chehalis
Cinebar
Morton

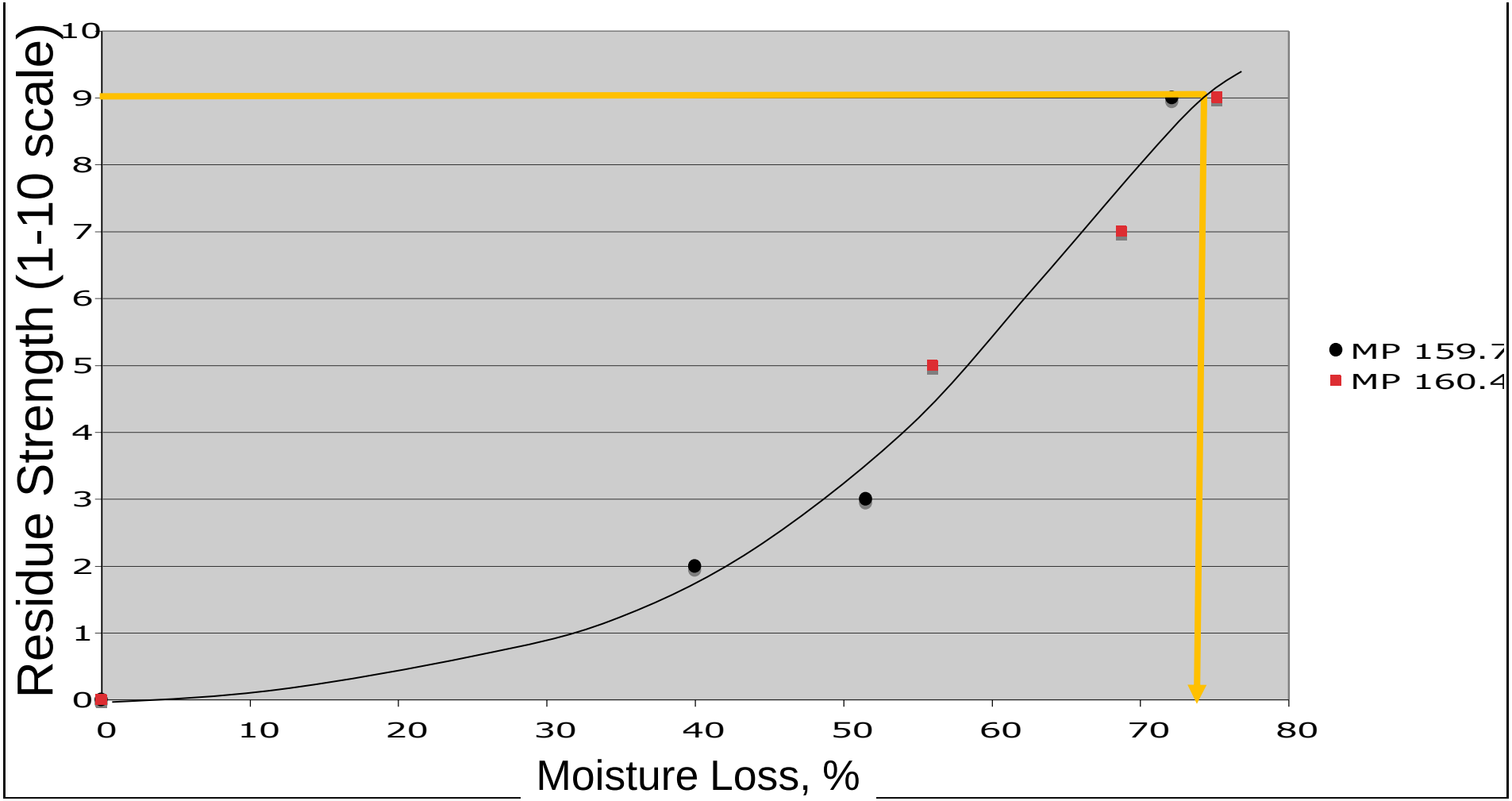
Arches, NP


Residue Strength (1-10 scale)
10
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
Moisture Loss, %
Test
Test
Test

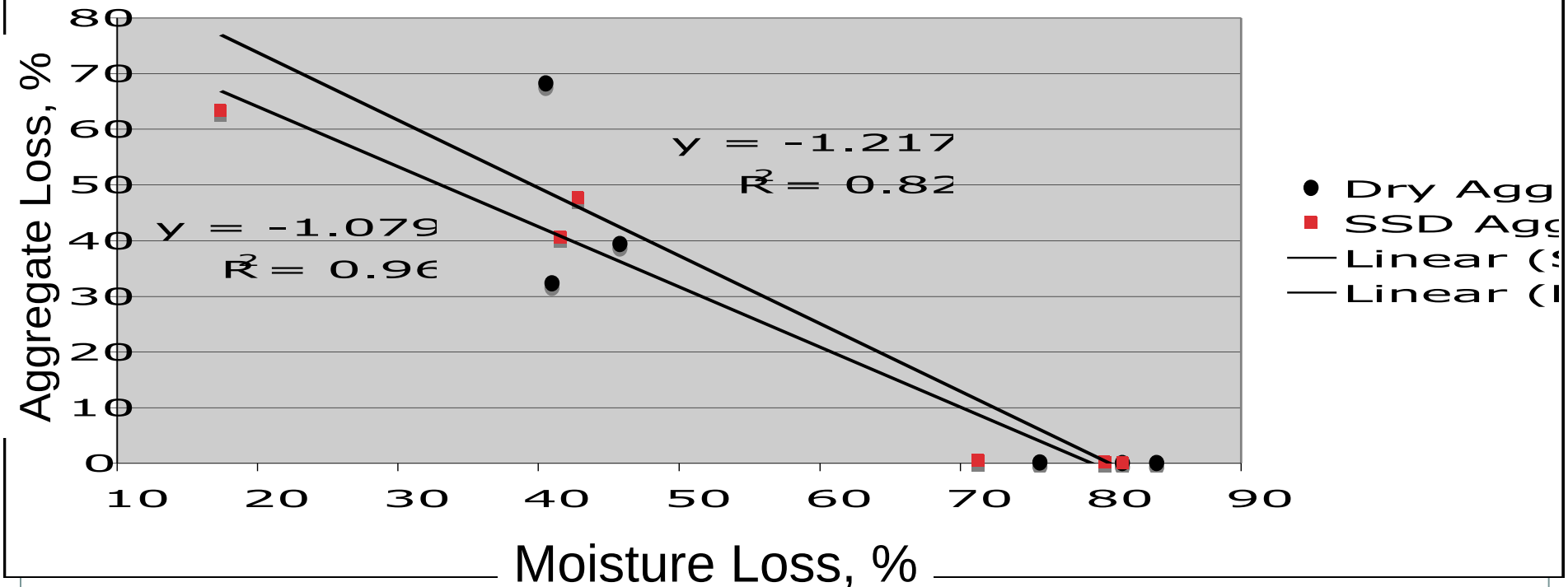
Frederick, CO



Forks, WA


Residue Strength (1-10 scale)
10
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
Moisture Loss, %
MP 159.7
MP 160.4

Chip Loss
Field Site Aggregates - Lab Sweep Test Results



Conclusions

- Certain Quantitative Measures Were Demonstrated Which Can Replace Subjective Decisions During Chip Seal Design and Construction

These Were:

Surface Texture

Surface Hardness

Simple Field Viscosity

Embedment Depth

Time to Sweeping and/or Traffic

Conclusions

- A chip seal performance test was developed for measuring strength of aggregate/emulsion combinations

Conclusions

- The amount of water remaining in the chip seal emulsion appears directly related to residue strength and hence, chip retention.

Conclusions

- Significantly higher chip loss was measured for test specimens fabricated with dry aggregates compared with saturated surface dry aggregates.

Conclusions

- This Data Suggests the New Sweep Test May be Used to Predict "Time to Traffic/Sweeping" for Fresh Chip Seals based on Moisture.


Thank You !