THE UNIVERSITY OF TEXAS AT TYLER

College of Engineering

Material Properties of Recycled Concrete Aggregates (RCA) for Improved Sustainability of Reinforced Concrete Building Structures

Andres de la Rosa

Department of Civil Engineering, University of Texas at Tyler, USA

(adelarosa3@patriots.uttyler.edu)

What is RCA?

/http://news.thomasnet.com/imt/2012/10/31/used-concrete-once-for-the-landfill-now-heads-to-recycling-facilities

Where Does it come from?

http://www.franklincontractors.biz/content/recycling.php, https://sites.google.com/site/eg1141031btanghoyungws/

Background & Motivation

1. Even though RCA can readily pass the prescriptive requirements for coarse aggregates in structural concrete (ASTM C33 2008), the variability in material properties and quality needs to be quantified and incorporated into design.
2. As a result, no engineering guidelines/standards currently exists for the design and construction of reinforced concrete utilizing RCA.
3. Little or no previous works exists on the service and ultimate load performance of prestressed and non-prestressed concrete structures utilizing RCA from U.S. sources.
4. Little or no previous work exists to quantify the economic and environmental benefits of using RCA in structural applications

Outline

- Recycled Concrete Aggregate (RCA) Sample Collection
- Sample Gradations
- Natural Aggregate (NA) & RCA Properties/Relationships
- Concrete Mix Design
- Sorptivity/Relationships

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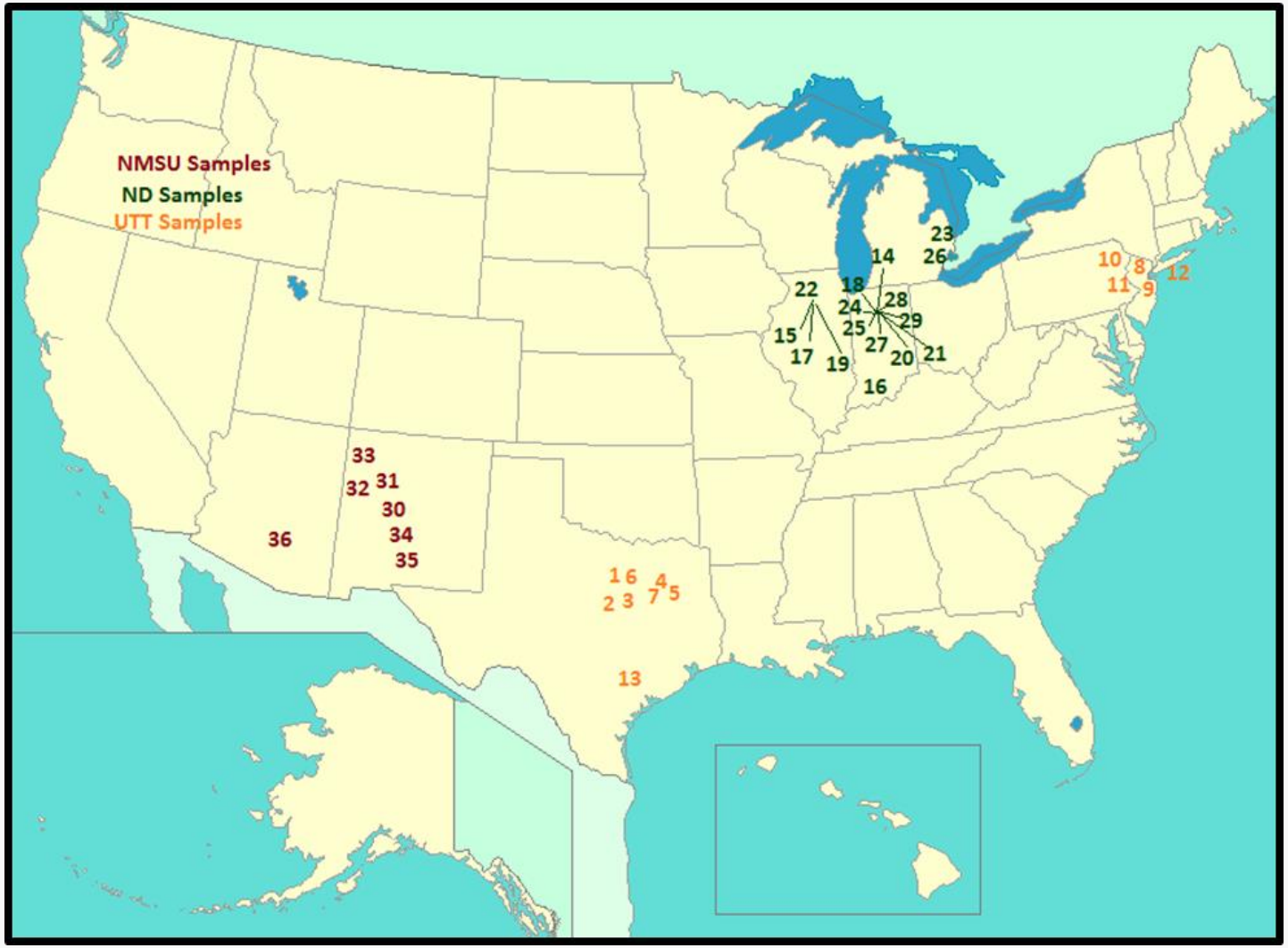
Collected Samples



ALL – 1.5” Minus (NY)

BCB - Base (TX)

BCL - 3” (TX)

BCM – 1.5” Minus (TX)

BCP – 2” Minus (TX)

BRS – 1.5” Minus (NJ)

CCF - 1.5” Minus (PA)

CCN - 1.5” to 0.375” Minus (PA)

MM – Rip-Rap (TX)

PRE – 2” Minus (TX)

SCC – 1.5” Minus (TX)

SMC – 3” Minus (TX)

TIL - 1.5” Minus (NJ)

Outline

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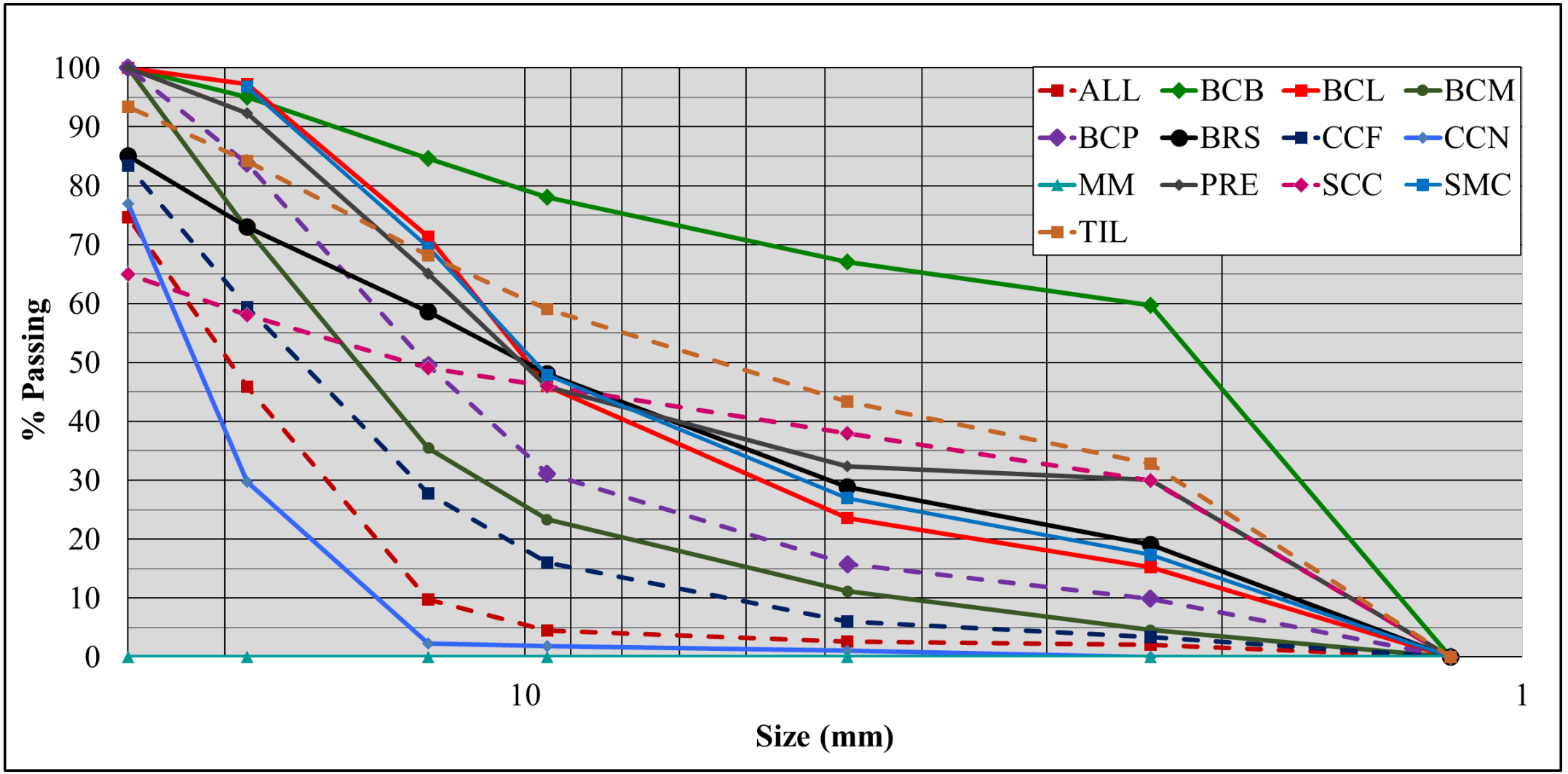
Gradations


100
90
80
70
60
50
40
30
20
10
0
% Passing
10
1
Size (mm)
ALL
BCB
BCL
BCM
BCP
BRS
CCF
CCN
MM
PRE
SCC
SMC
TIL

Natural Aggregate (NA) and Recycled Concrete Aggregate (RCA) Properties

State of Origin	Sample	Type	Absorption (%)	Bulk SG	Bulk SSD	Apparent SG	DRCA (%)	RMRCA (%)
NY	ALL	RCA	5.33	2.23	2.35	2.53	29.1	26.0
TX	BCB	RCA	5.95	2.28	2.42	2.64	2.29	42.3
TX	BCL	RCA	5.52	2.29	2.42	2.62	2.96	34.7
TX	BCM	RCA	5.13	2.31	2.42	2.61	3.39	24.4
TX	BCP	RCA	5.42	2.3	2.42	2.62	3.32	33.1
NJ	BRS	RCA	2.38	2.48	2.53	2.63	35.1	18.5
PA	CCF	RCA	5.01	2.33	2.45	2.64	5.95	26.9
PA	CCN	RCA	5.02	2.33	2.44	2.63	10.3	26.7
TX	MM	RCA	7.24	2.21	2.37	2.63	0	54.7
TX	PRE	RCA	5.61	2.3	2.43	2.64	1.87	30.1
TX	SCC	RCA	9.68	1.94	2.13	2.39	13.7	59.7
TX	SMC	RCA	6.23	2.22	2.36	2.58	19.9	51.2
NJ	TIL	RCA	5.41	2.31	2.43	2.64	4.63	32.2
TX	G	NA	0.26	2.64	2.64	2.66	-	-
TX	PG	NA	1.83	2.55	2.6	2.68	-	-
TX	B	NA	10.5	1.48	1.63	1.75	-	-
TX	SND	NA	1.00	2.62	2.65	2.69	-	-

NA and RCA Properties

State of Origin	Sample	Type	Absorption (%)	Bulk SG	Bulk SSD	Apparent SG	DRCA (%)	RMRCA (%)
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TX	G	NA	0.26	2.64	2.64	2.66		-
TX	PG	NA	1.83	2.55	2.6	2.68	-	-
TX	B	NA	10.5	1.48	1.63	1.75	-	-
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BRS

MM

NA and RCA Properties

State of Origin	Sample	Type	Absorption (%)	Bulk SG	Bulk SSD	Apparent SG	DRCA (%	RMRCA (%)
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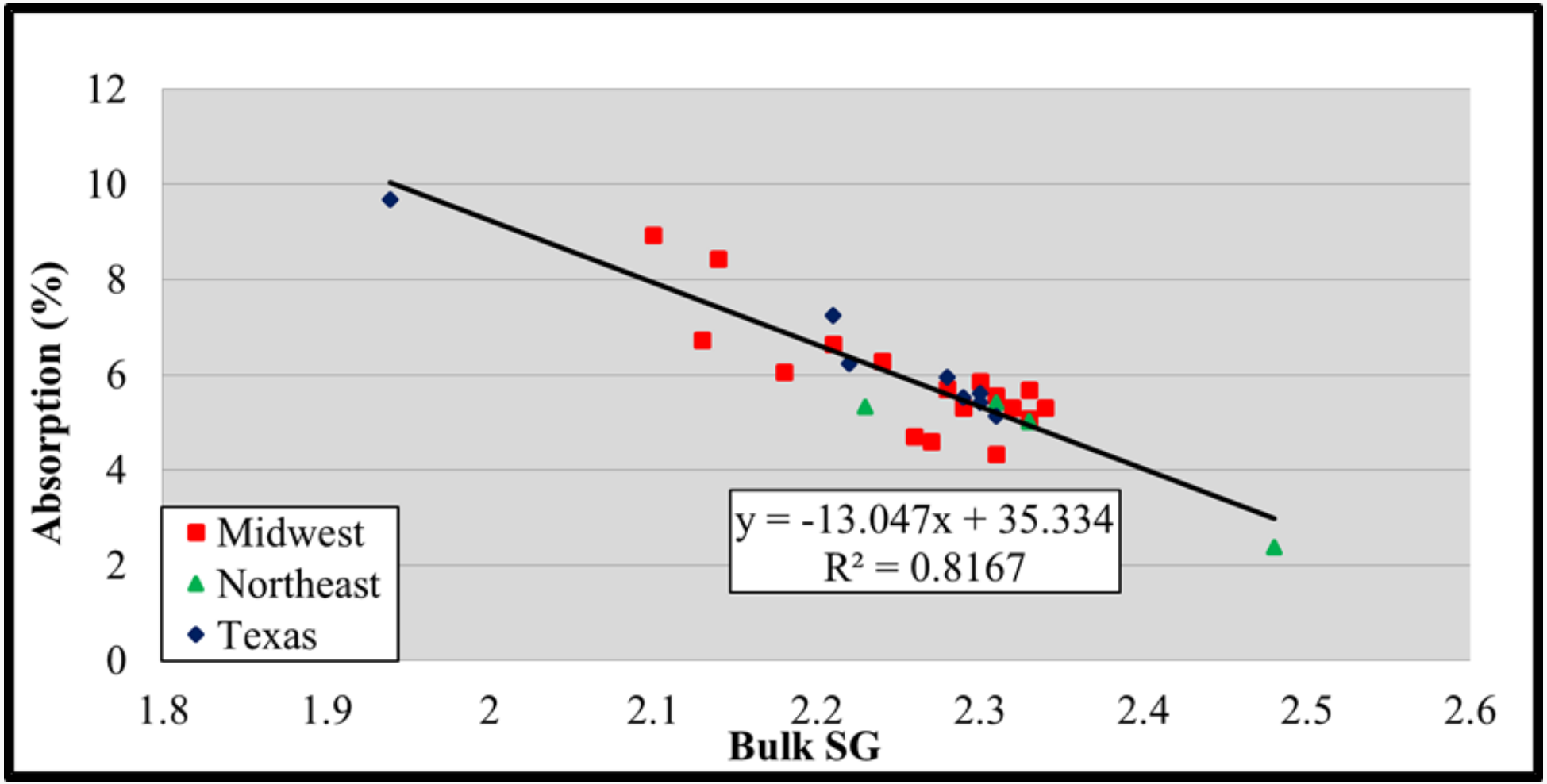
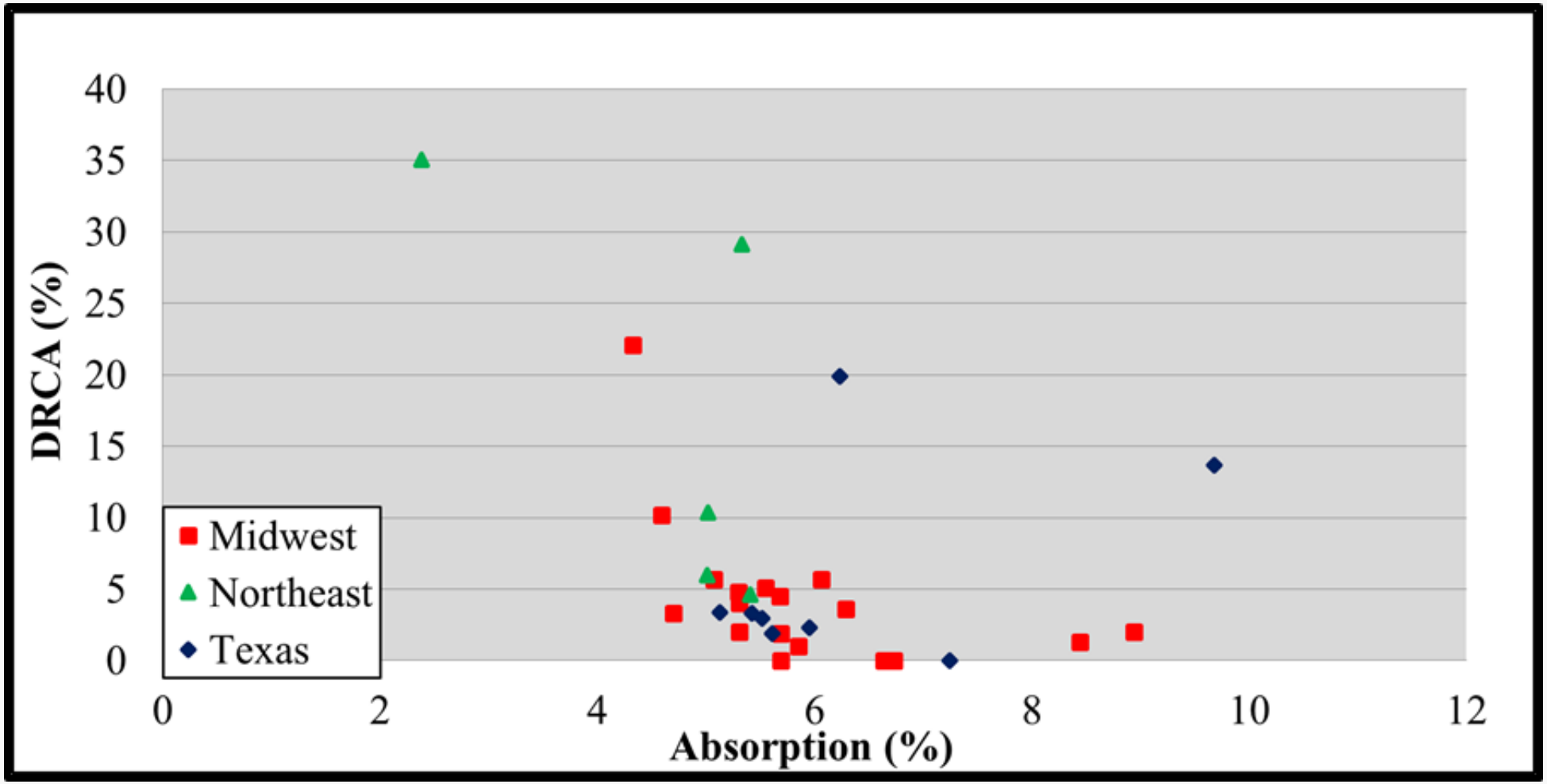
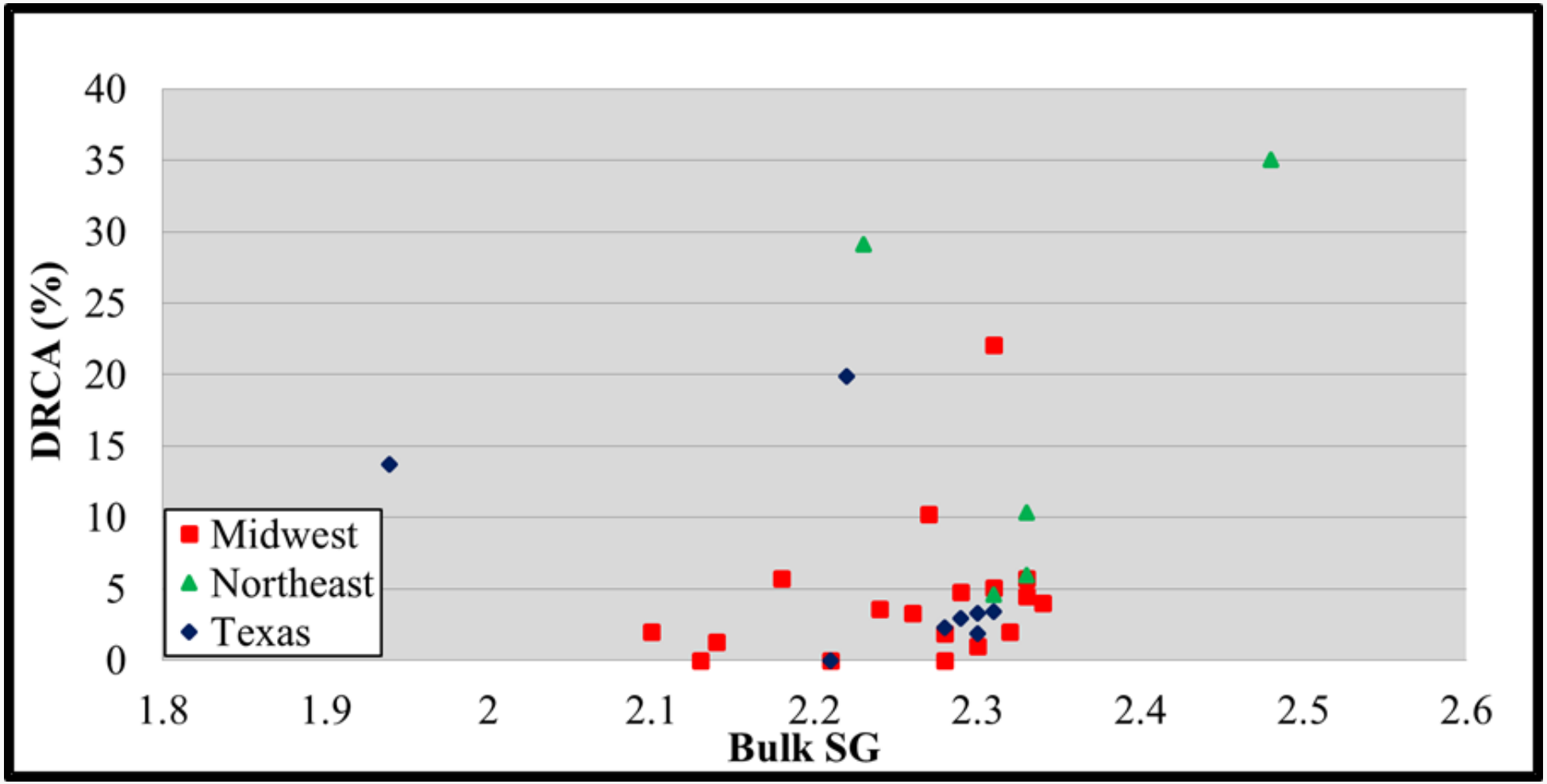
Absorption vs. Specific Gravity (SG)



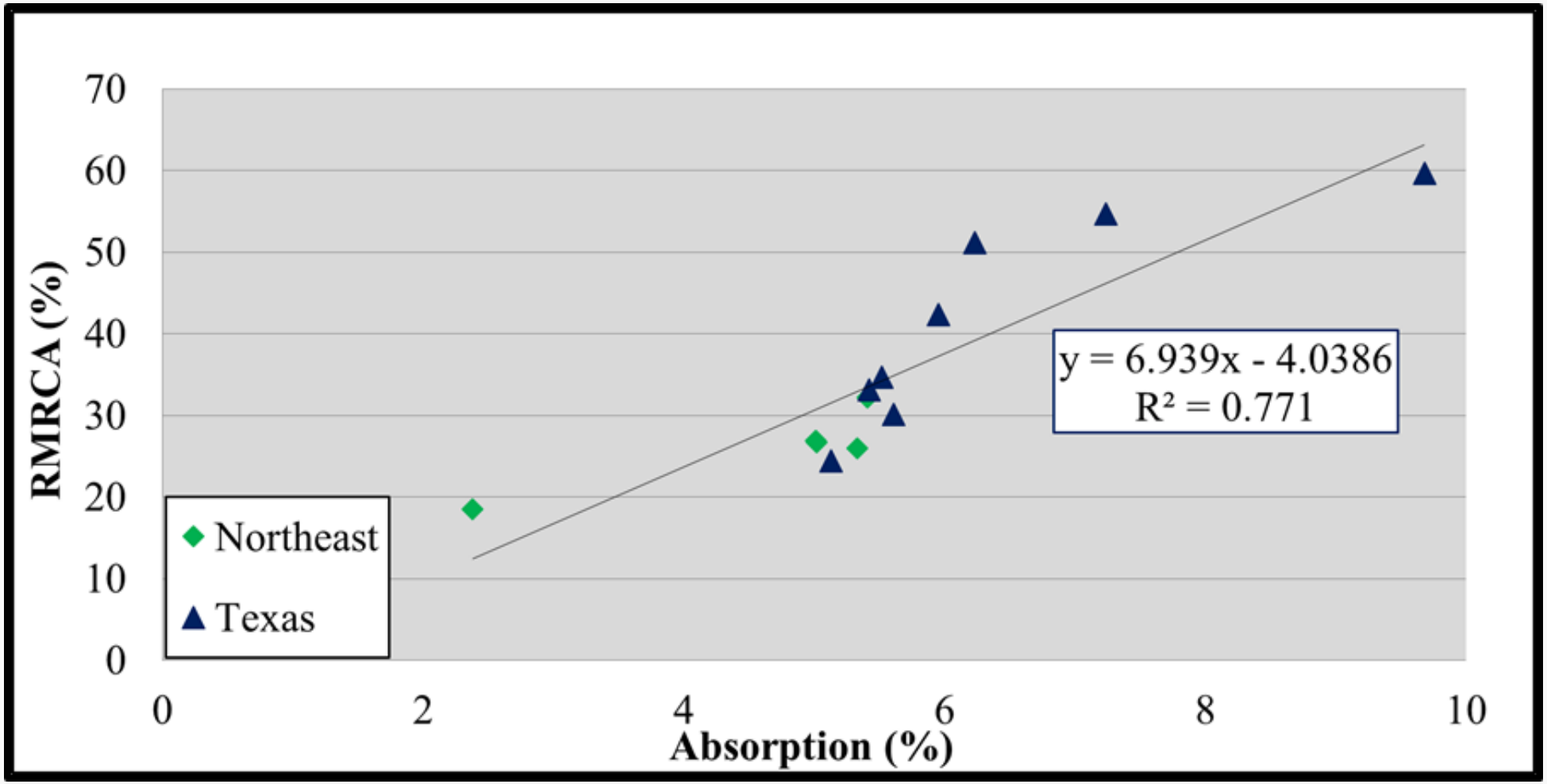
Deleterious Material (DRCA) vs Absorption



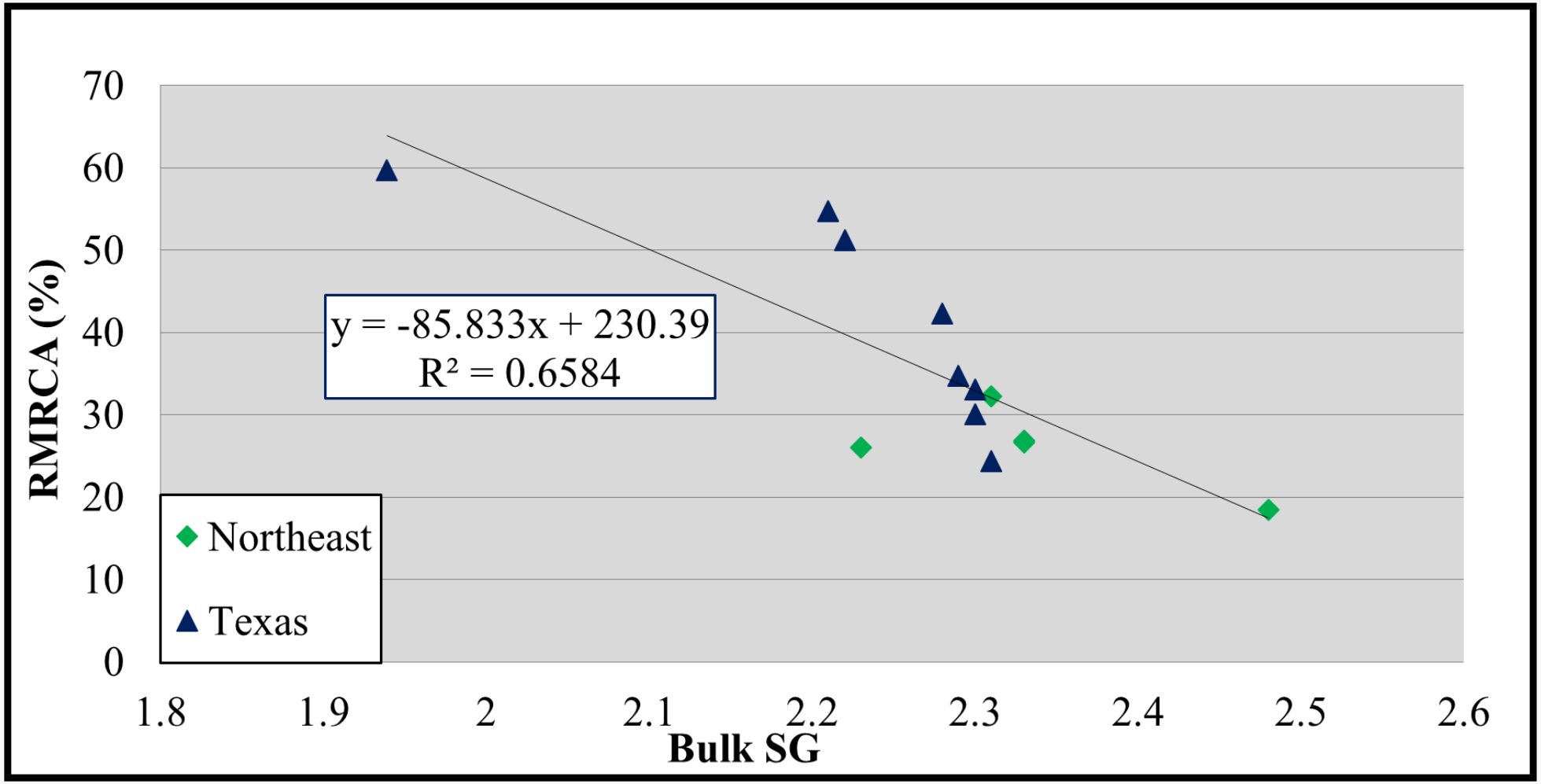
DRCA vs Bulk SG



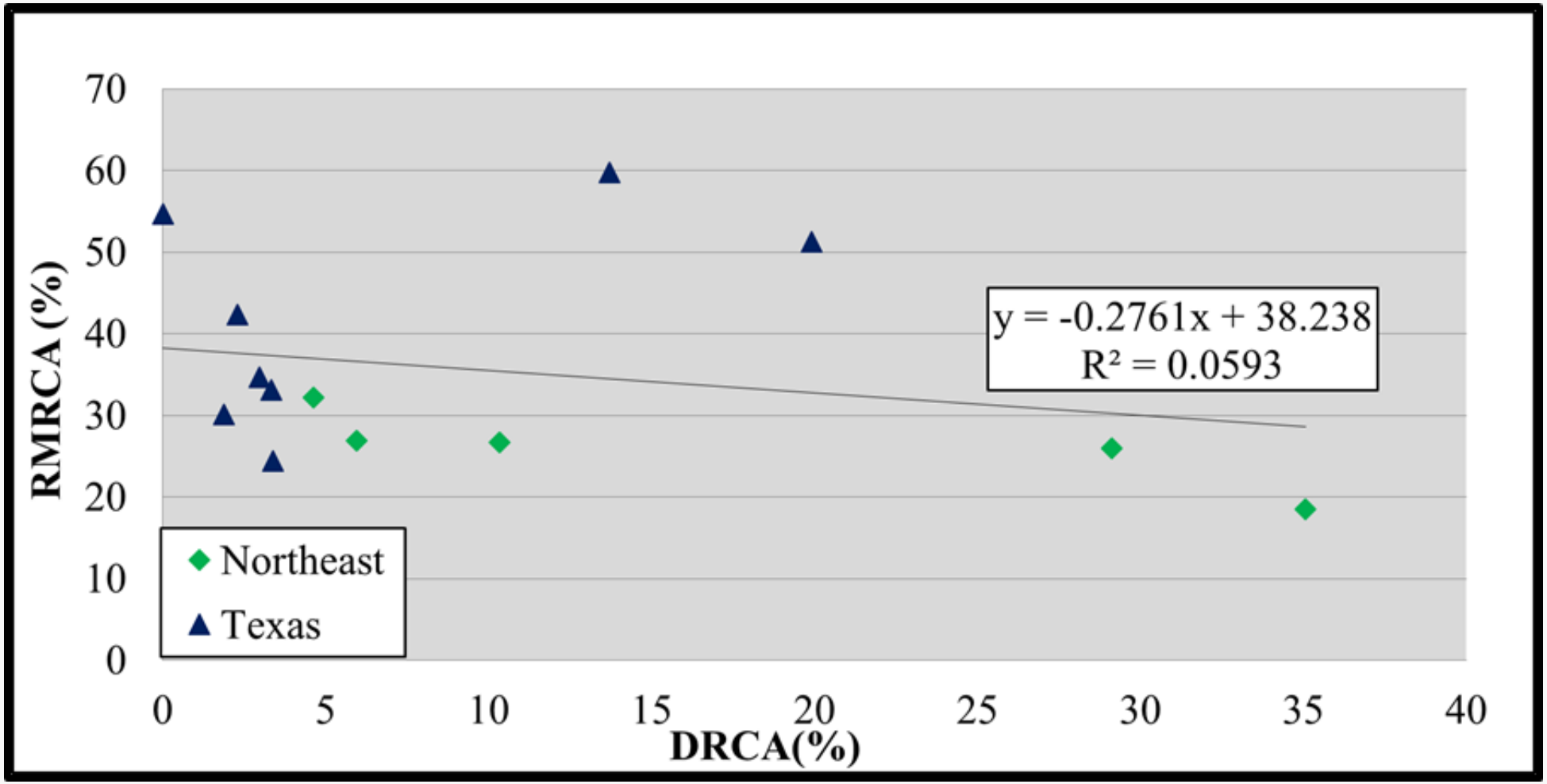
Residual Mortar (RMRCA) vs Absorption (UTT)



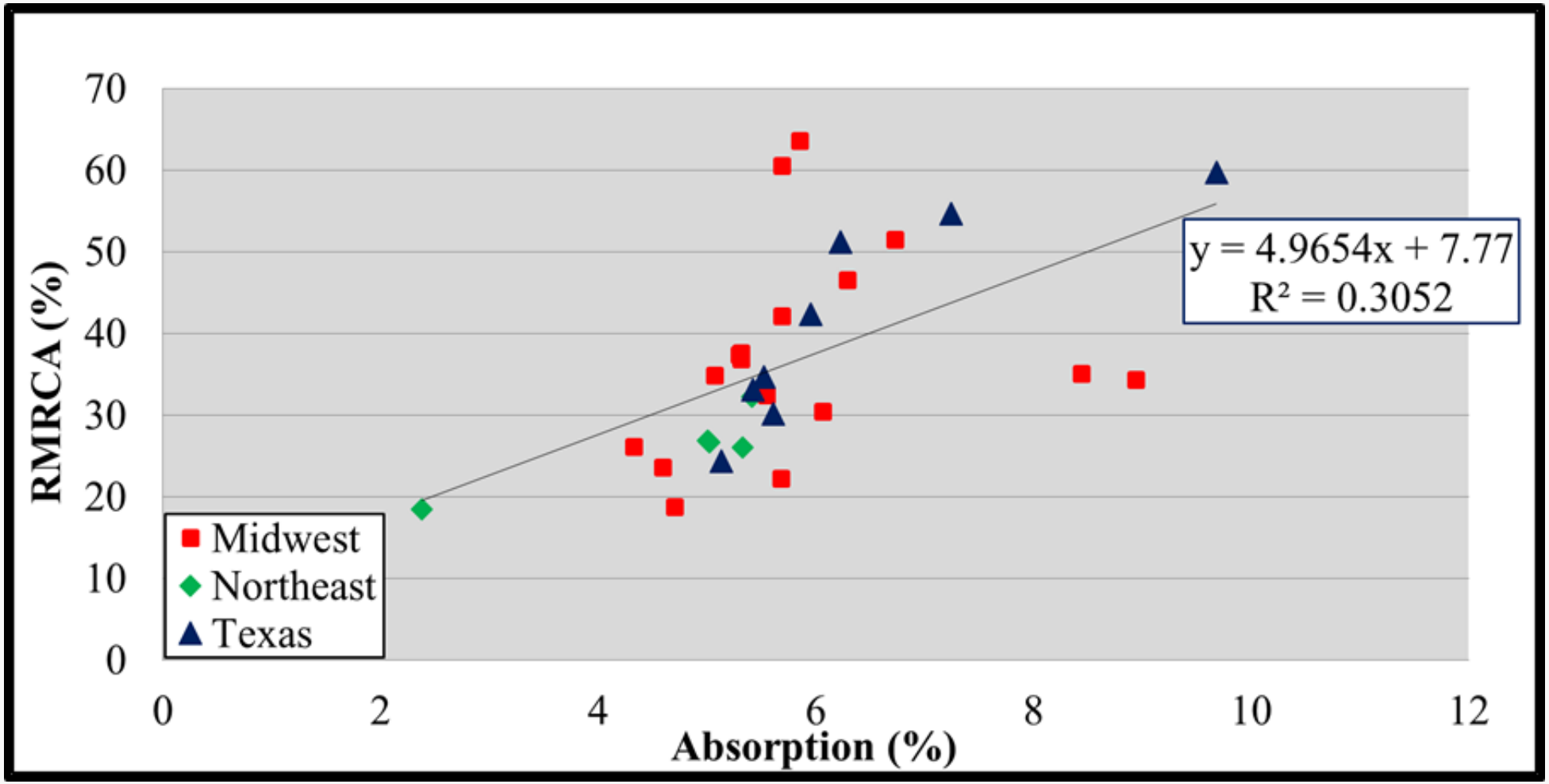
RMRCA vs Bulk SG (UTT)



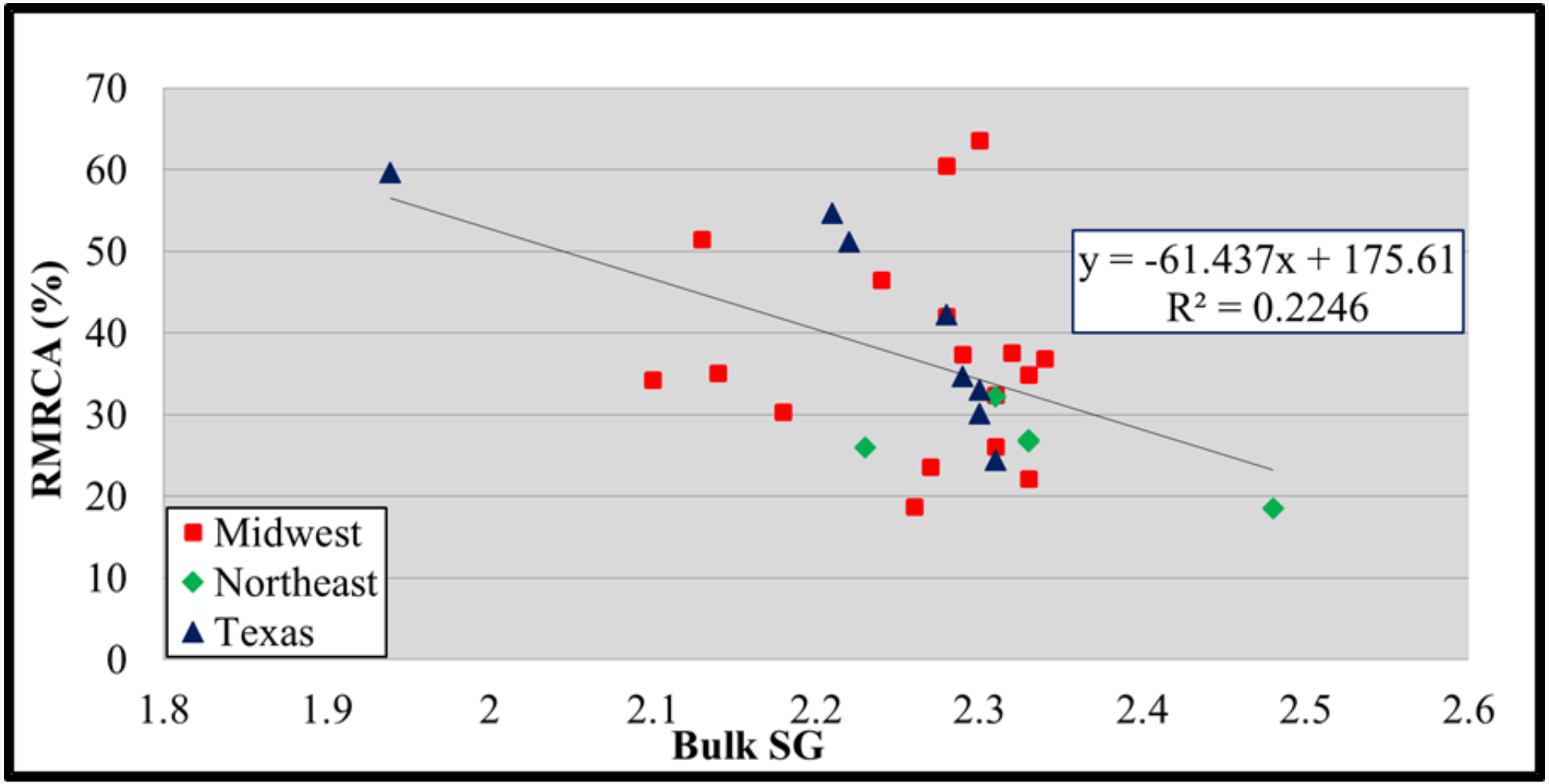
RMRCA vs DRCA (UTT)



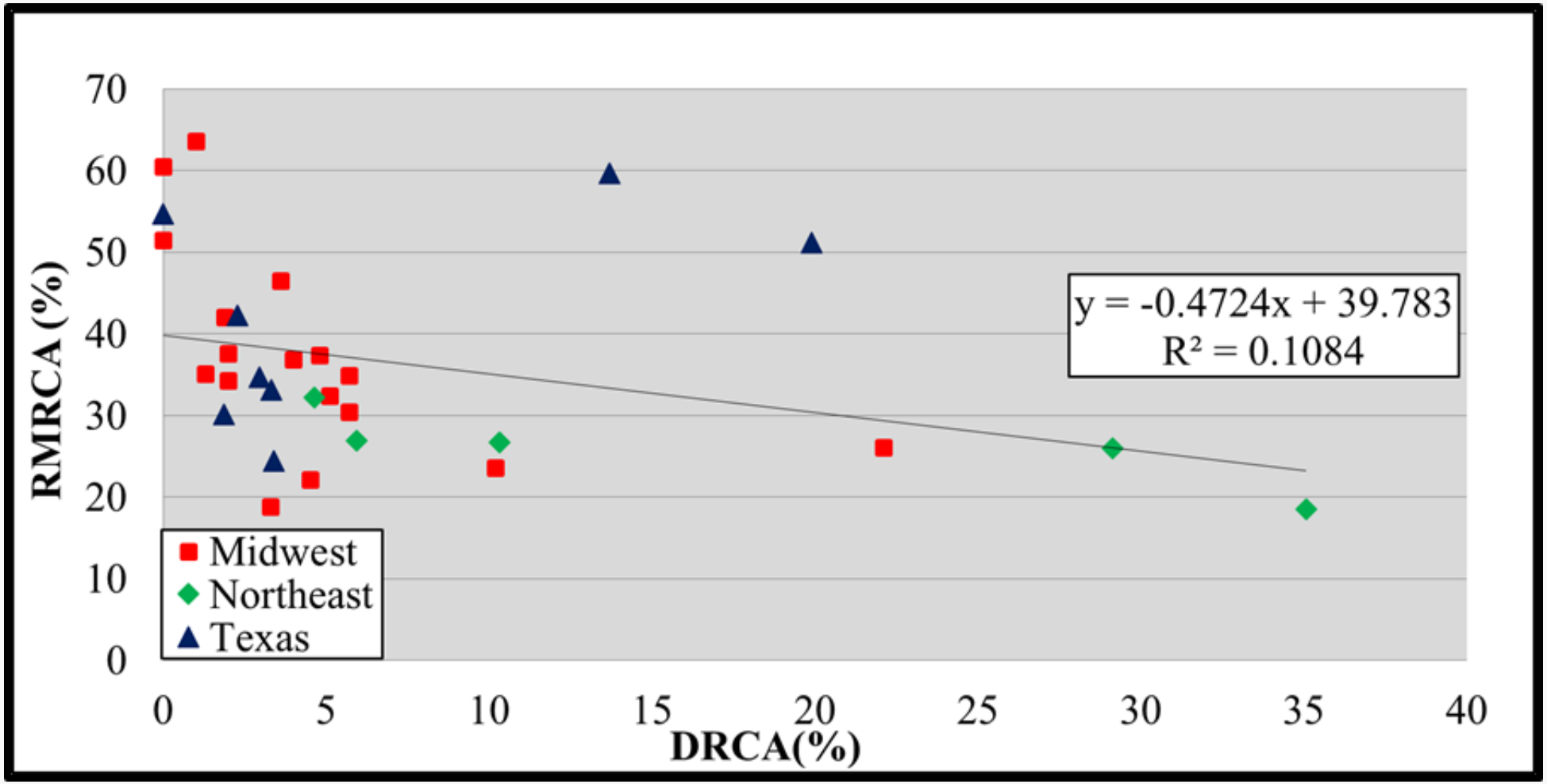
RMRCA vs Absorption



RMRCA vs Bulk SG



RMRCA vs DRCA



Outline

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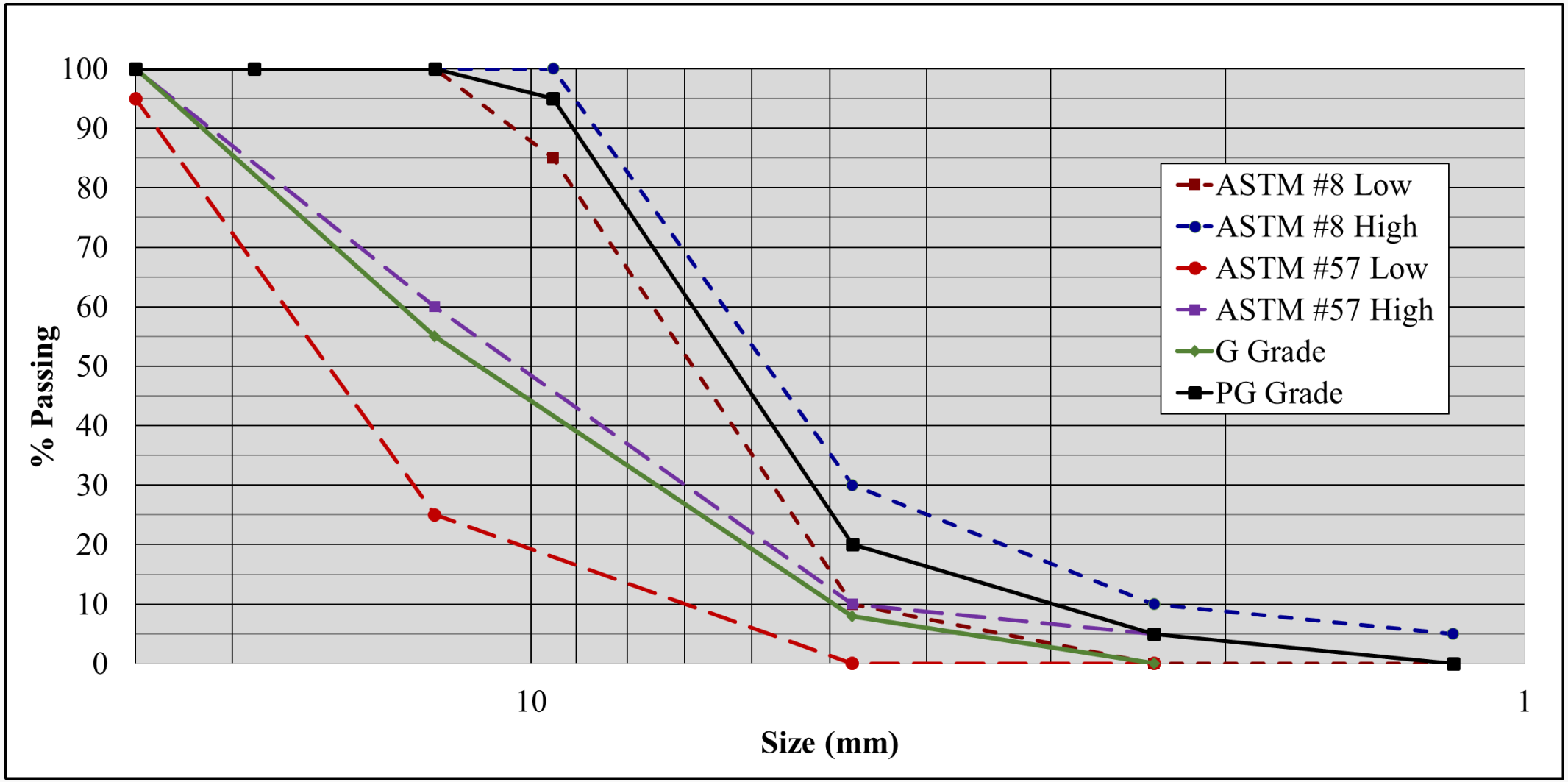
- Sample Gradations
- Natural Aggregate (NA) & RCA Properties/Relationships
- Concrete Mix Design
- Sorptivity/Relationships

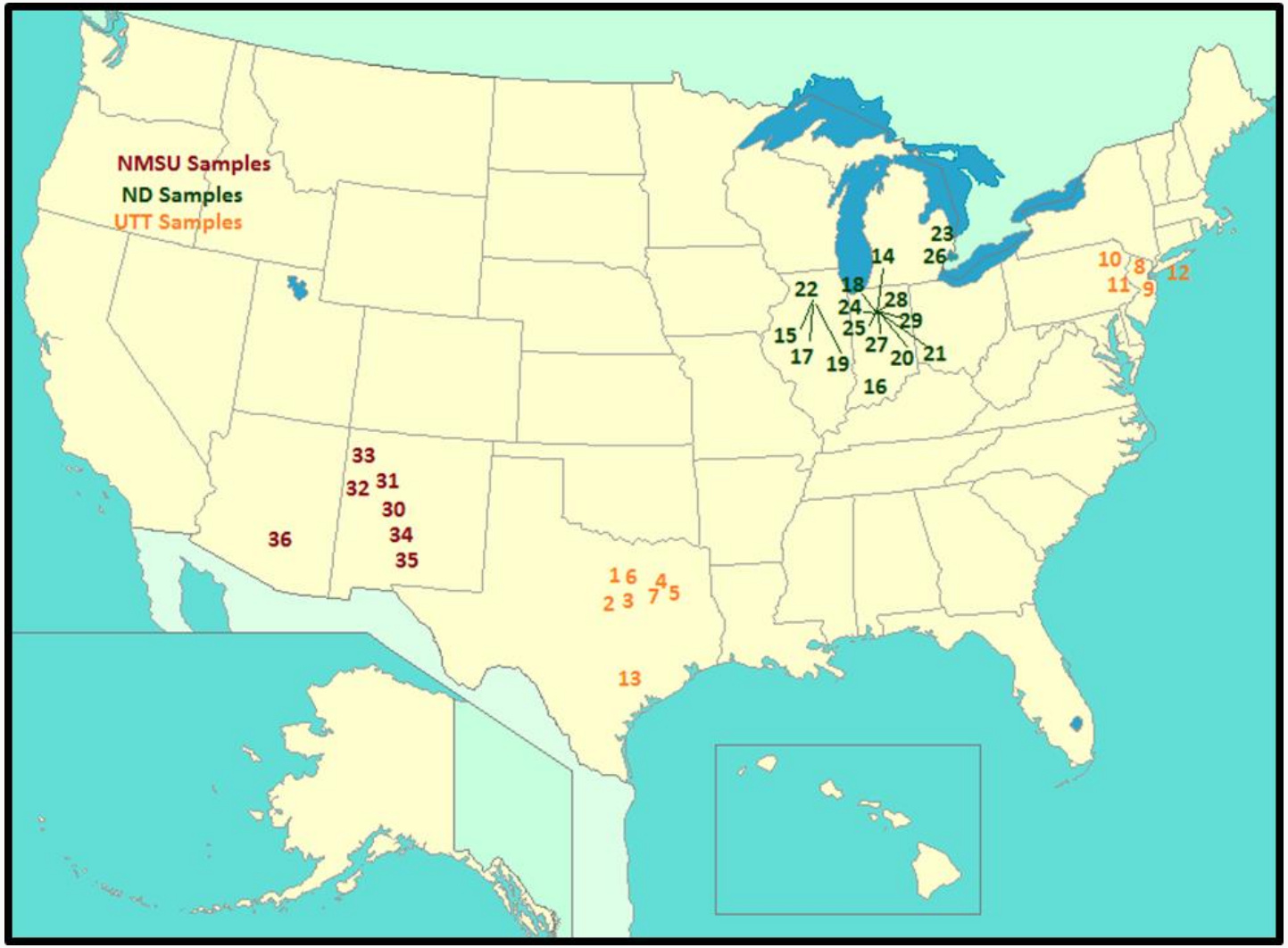
Target Gradations



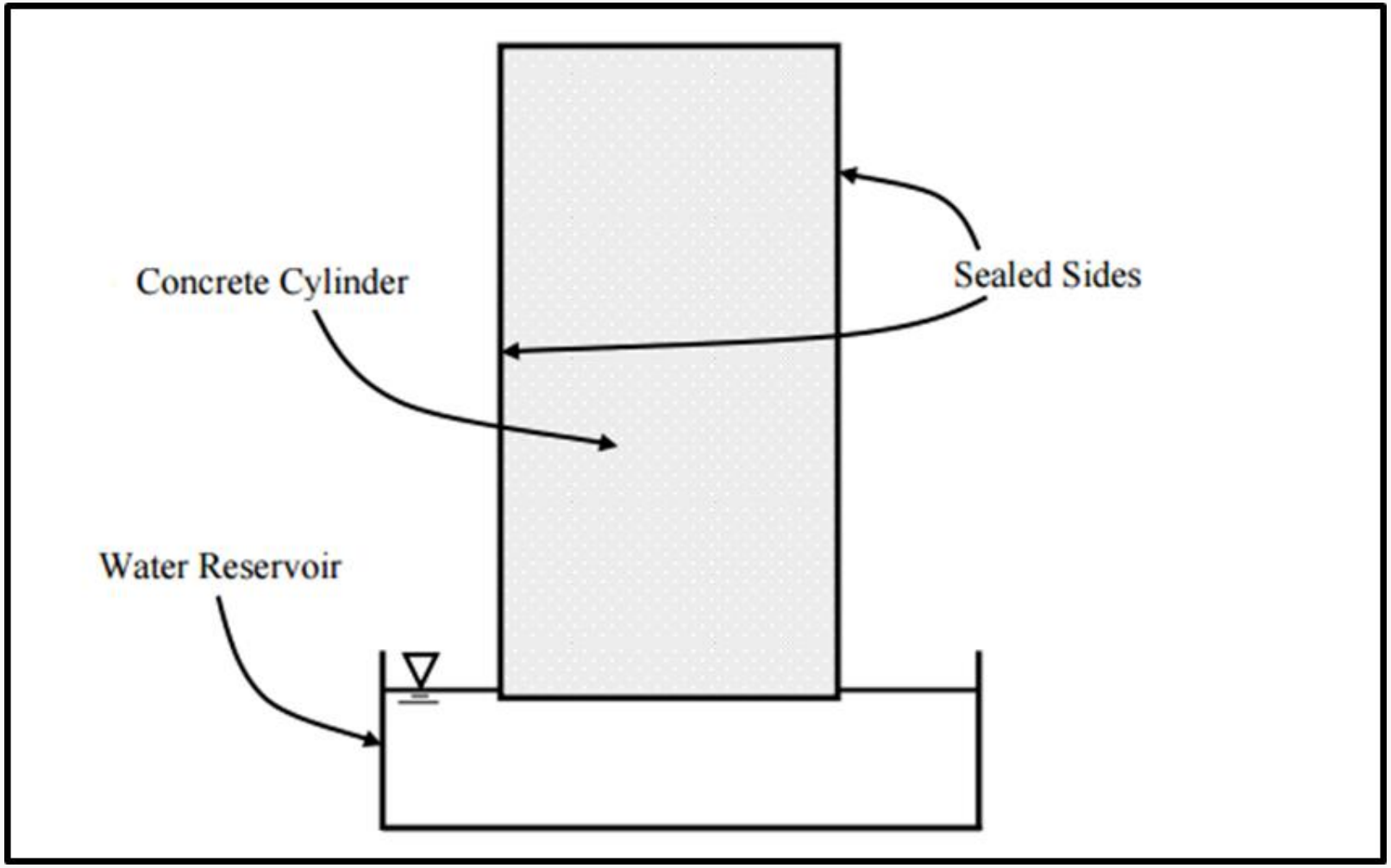
Mix Designs

Mix Design	M1	M5
Type	Normal Strength	High Strength
Target Compressive Strength (psi)	6000	8000
Target Air Content (%)	5	6
Amount of Cement (%)	16.6	21.2

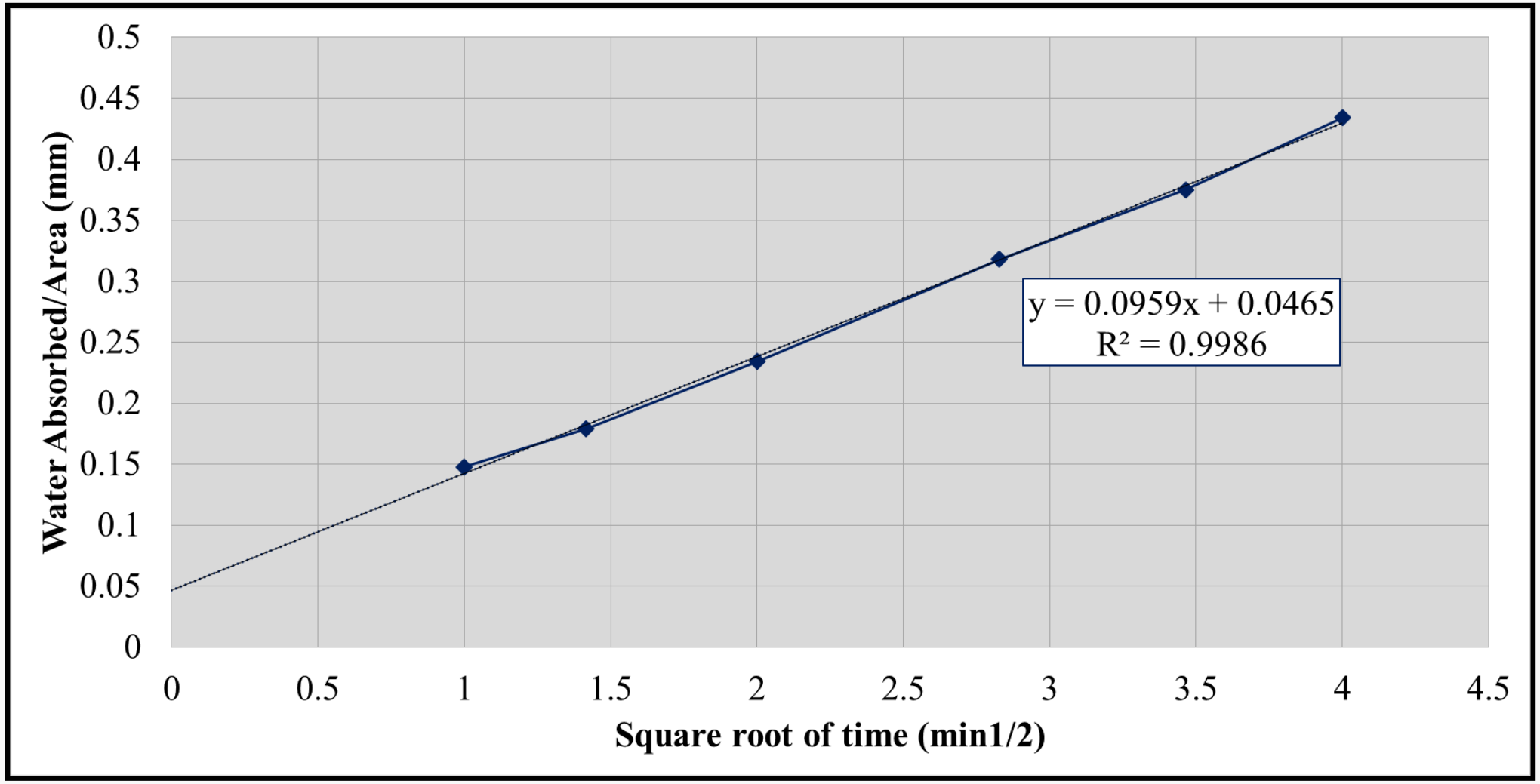
Collected Samples



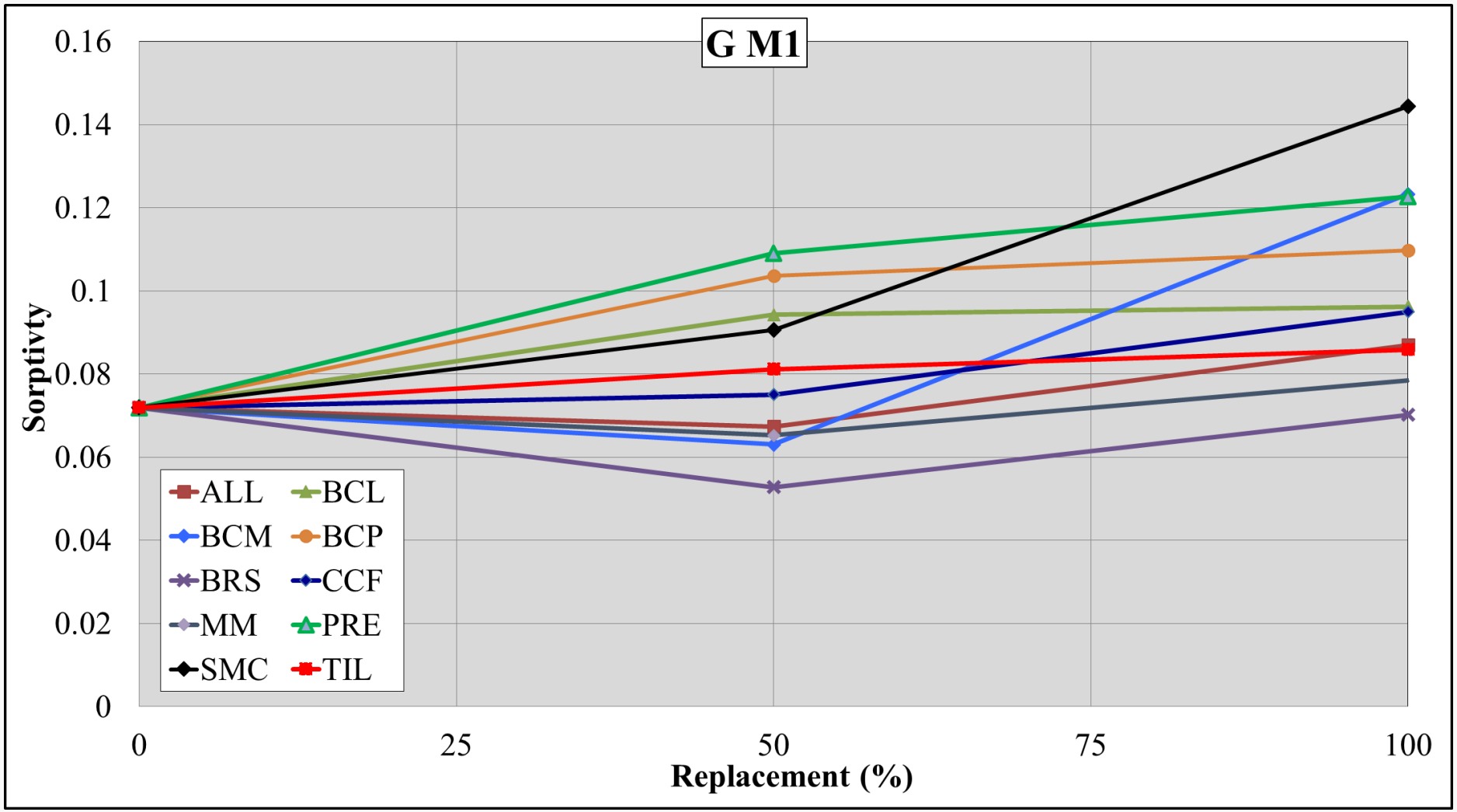
What is Sorptivity?



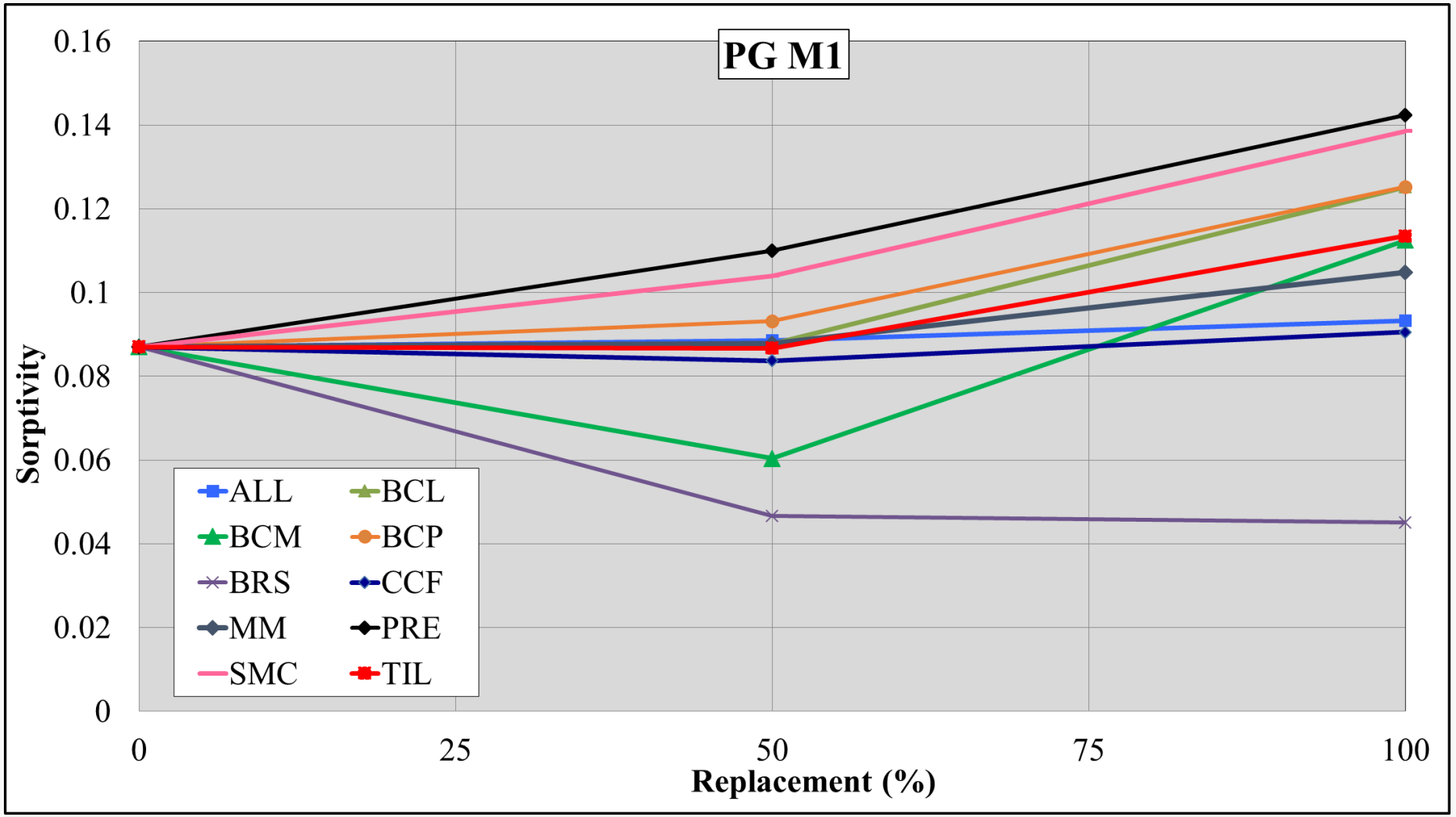
Typical Sorptivity Plot



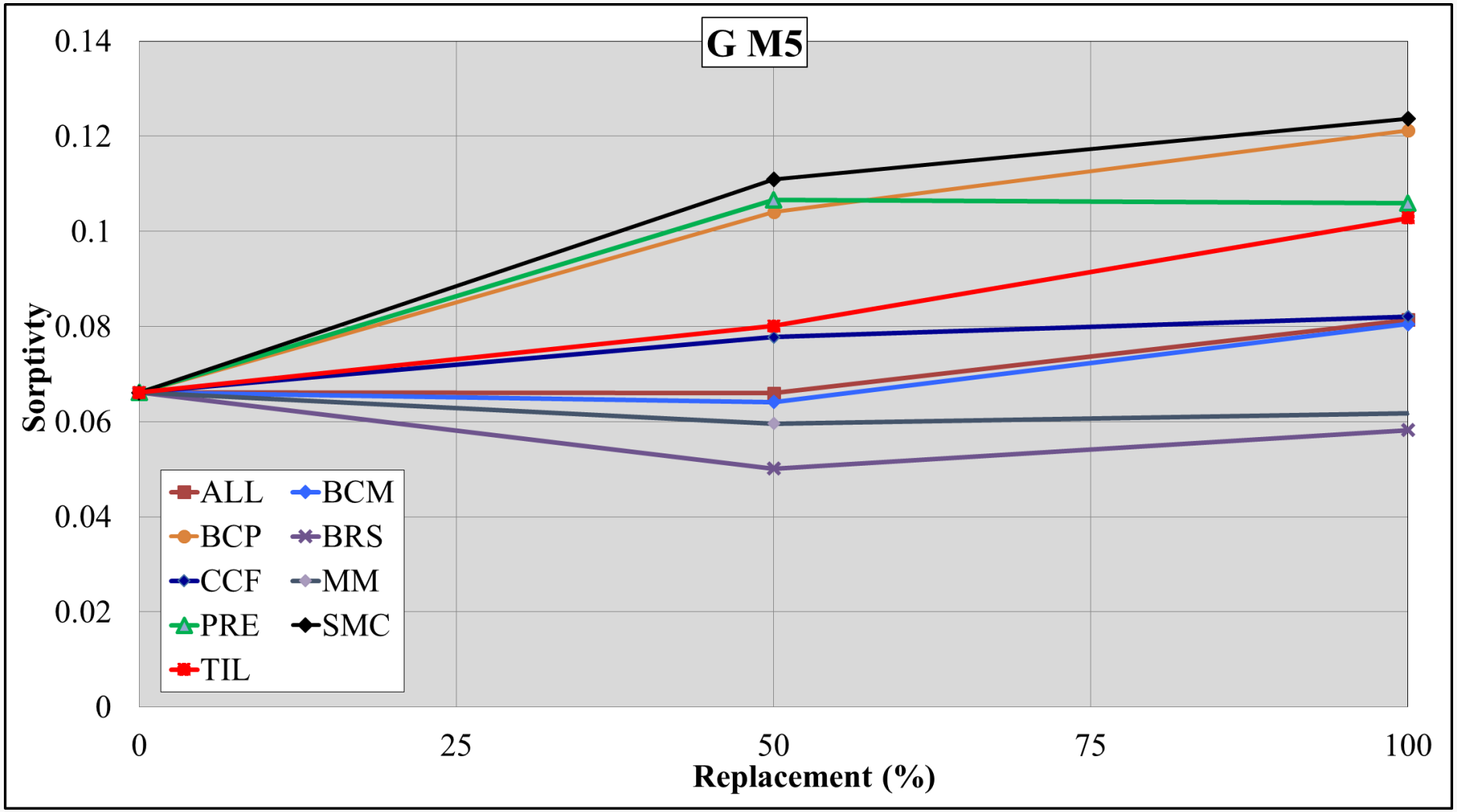
Sorptivity Results – G M1



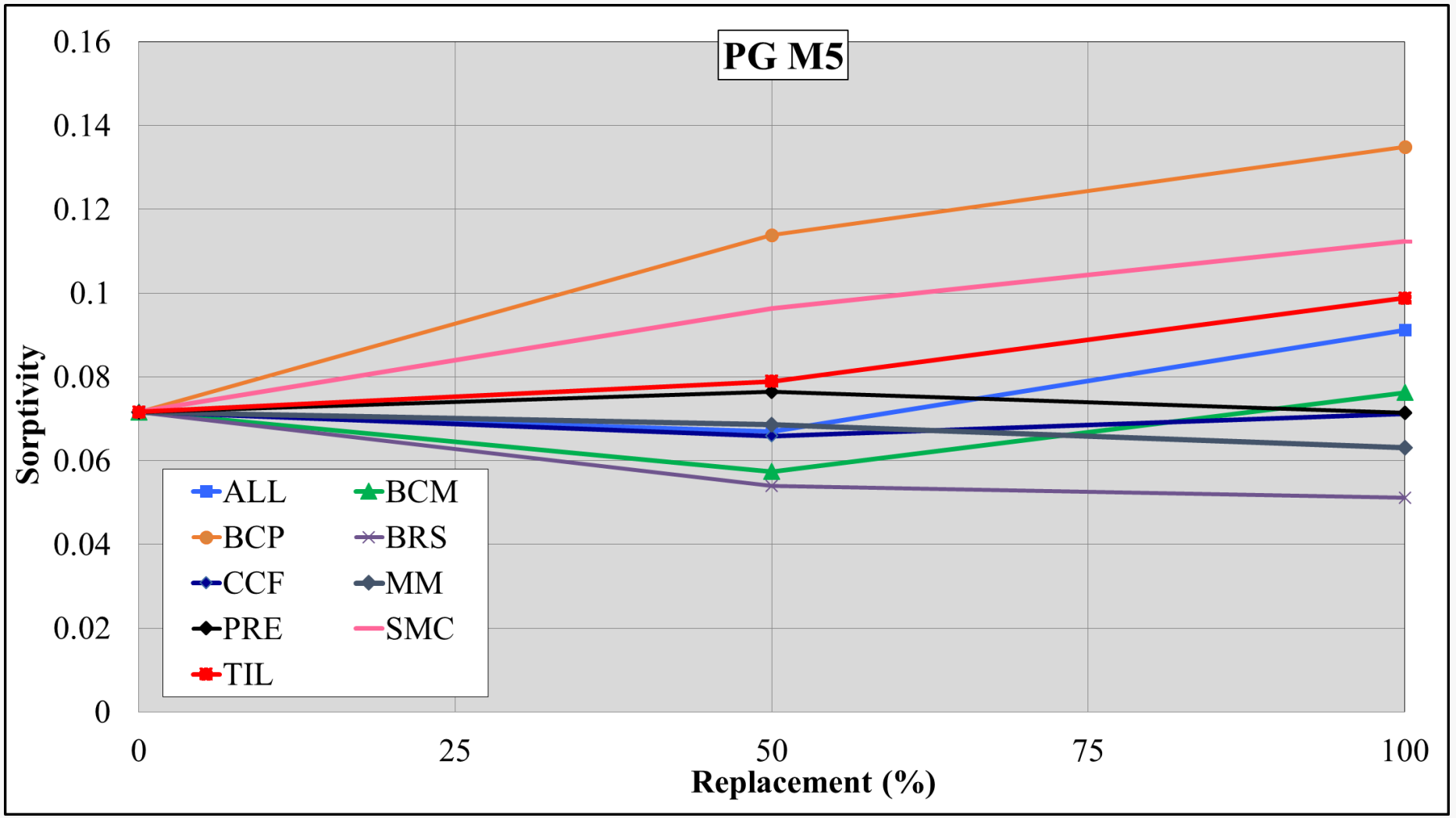
Sorptivity Results – PG M1



Sorptivity Results – G M5



Sorptivity Results – PG M5



Percent Difference – M1

Sample	G M1		PG M1	
	Percent Difference from 0 to 50%	Percent Difference from 0 to 100%	Percent Difference from 0 to 50%	Percent Difference from 0 to 100%
ALL	-6.5	19.0	7.0	14.5
BCL	23.8	28.9	0.8	36.0
BCM	-28.9	52.7	-36.1	25.6
BCP	36.1	41.6	6.9	36.0
BRS	-30.6	-2.4	-60.3	-63.4
CCF	4.4	27.7	3.9	4.1
MM	-9.6	8.8	1.0	18.7
PRE	41.1	52.2	23.4	48.3
SMC	23.0	67.0	17.8	45.7
TIL	12.2	17.7	-0.4	26.4
±	42.0	68.0	61.0	64.0
Avg.	6.5	31.3	-3.6	19.2

Percent Difference – M1

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BCL	23.8	28.9	0.8	36.0
BCM	-28.9	52.7	-36.1	25.6
BCP	36.1	41.6	6.9	36.0
BRS	-30.6	-2.4	-60.3	-63.4
CCF	4.4	27.7	3.9	4.1
MM	-9.6	8.8	1.0	18.7
PRE	41.1	52.2	23.4	48.3
SMC	23.0	67.0	17.8	45.7
TIL	12.2	17.7	-0.4	26.4
±	42.0	68.0	61.0	64.0
Avg.	6.5	31.3	-3.6	19.2

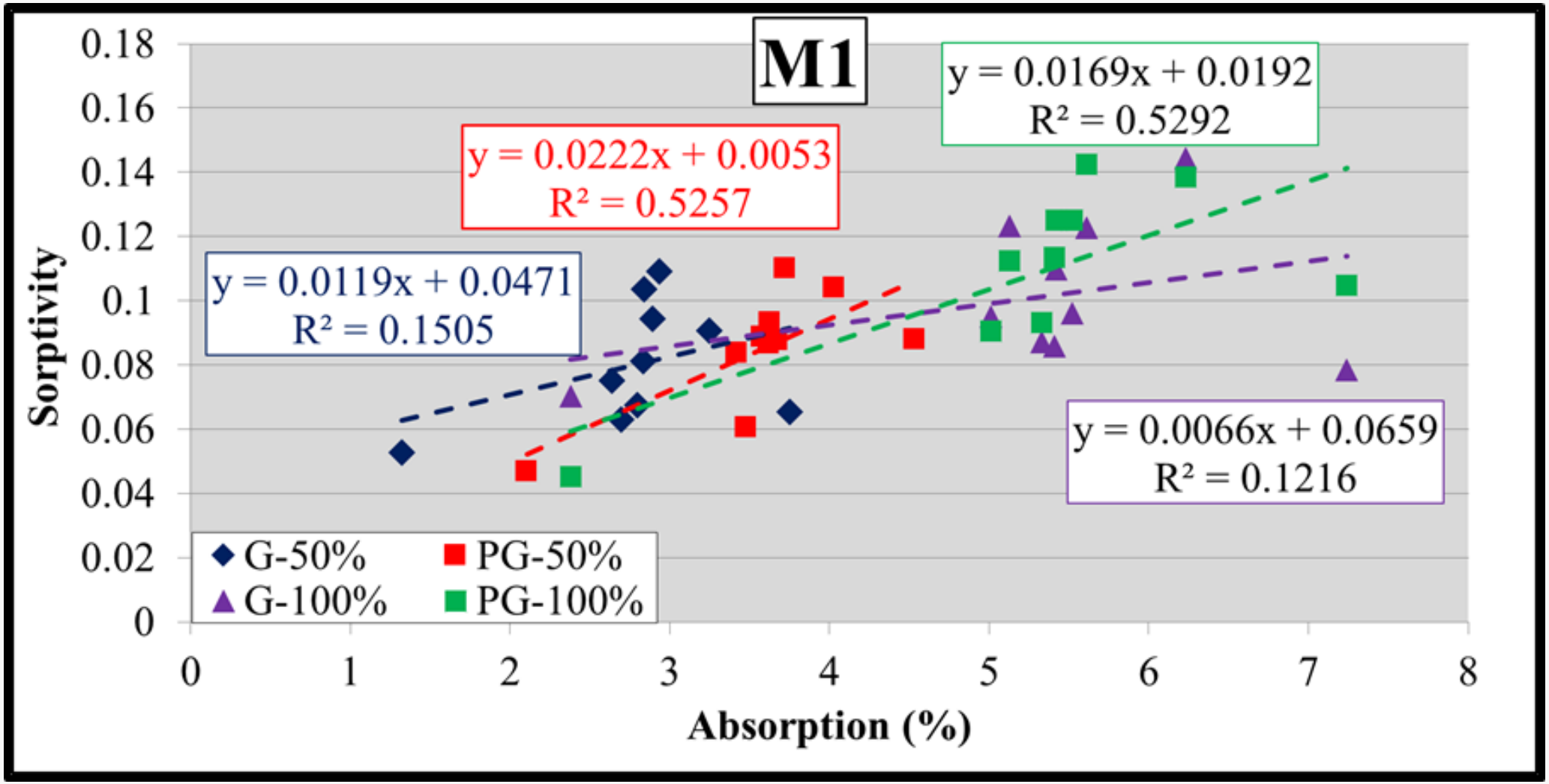
Percent Difference – M5

Sample	G M5		PG M5	
	Percent Difference from 0 to 50%	Percent Difference from 0 to 100%	Percent Difference from 0 to 50%	Percent Difference from 0 to 100%
ALL	-0.2	20.7	-6.8	24.1
BCM	-3.1	19.6	-22.0	6.4
BCP	44.7	58.8	45.5	61.3
BRS	-27.5	-12.7	-28.0	-33.2
CCF	16.3	21.6	-8.3	-0.6
MM	-10.3	-6.7	-4.3	-12.6
PRE	46.9	46.3	6.6	-0.3
SMC	50.7	60.7	29.5	44.3
TIL	19.2	43.5	9.7	31.9
±	51.0	61.0	46.0	62.0
Avg.	15.2	28.0	2.4	13.5

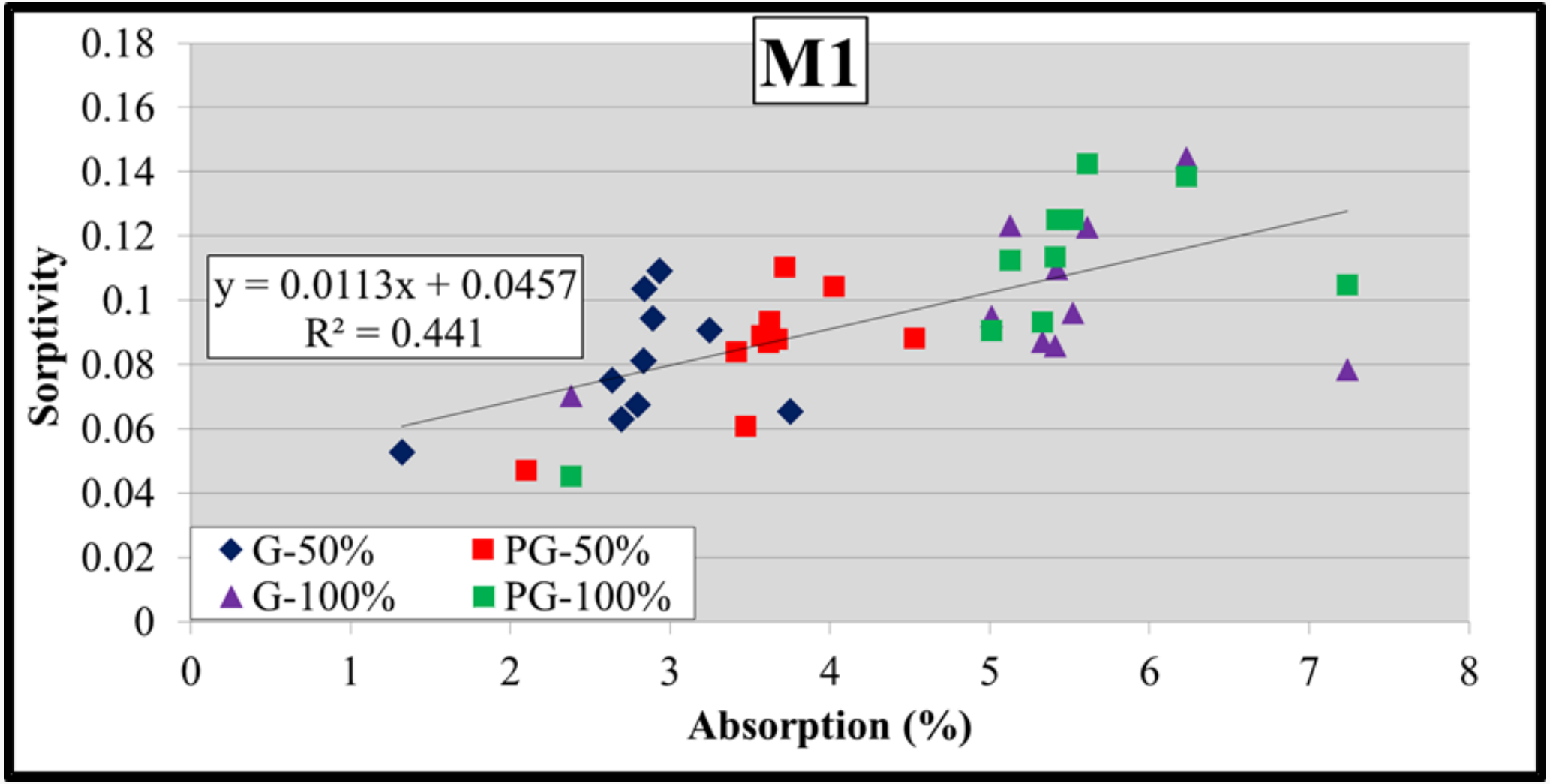
Percent Difference – M5

Sample	G M5		PG M5	
	Percent Difference from 0 to 50%	Percent Difference from 0 to 100%	Percent Difference from 0 to 50%	Percent Difference from 0 to 100%
ALL	-0.2	20.7	-6.8	24.1
BCM	-3.1	19.6	-22.0	6.4
BCP	44.7	58.8	45.5	61.3
BRS	-27.5	-12.7	-28.0	-33.2
CCF	16.3	21.6	-8.3	-0.6
MM	-10.3	-6.7	-4.3	-12.6
PRE	46.9	46.3	6.6	-0.3
SMC	50.7	60.7	29.5	44.3
TIL	19.2	43.5	9.7	31.9
±	51.0	61.0	46.0	62.0
Avg.	15.2	28.0	2.4	13.5

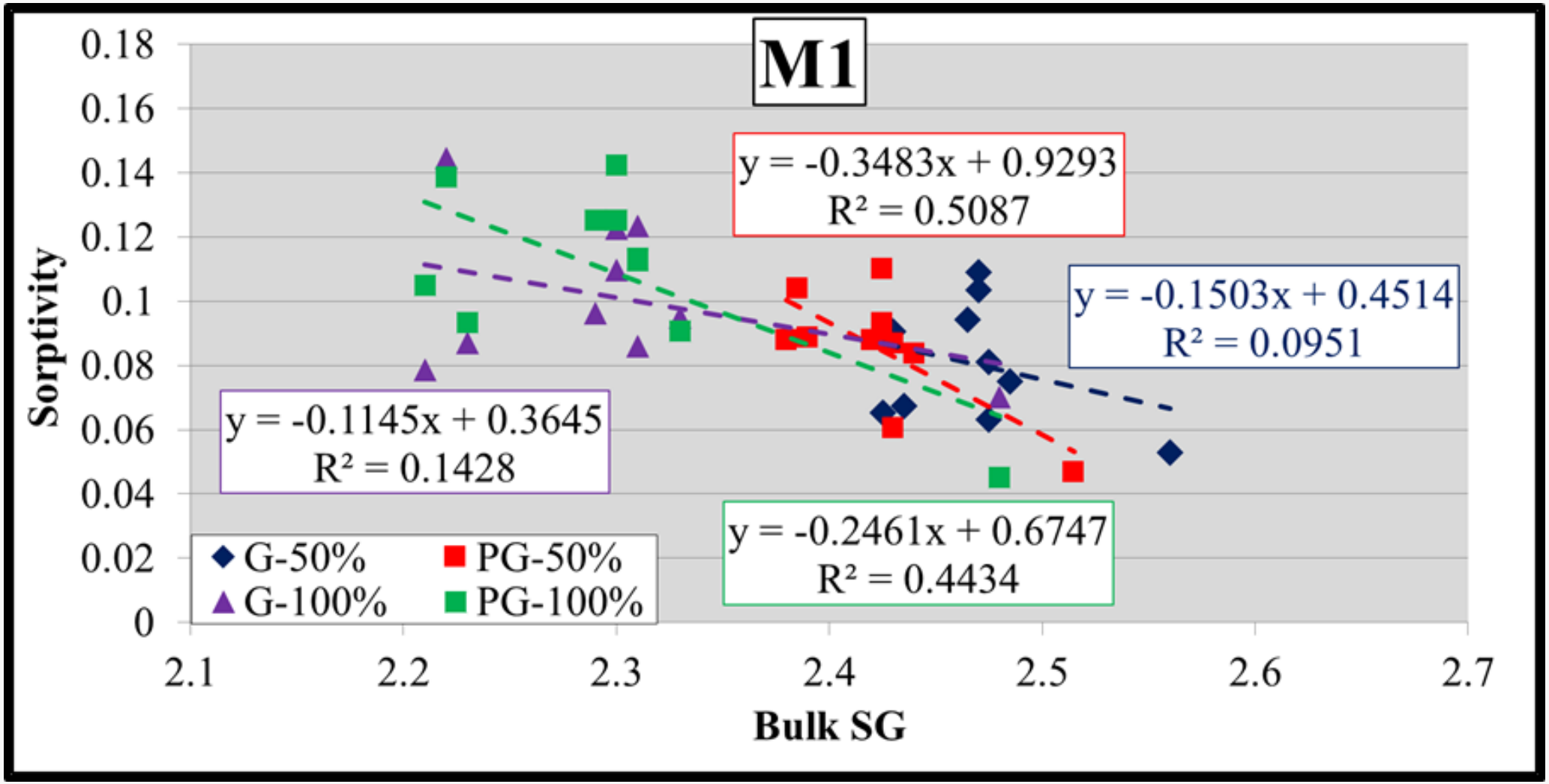
Sorptivity vs. Absorption - M1



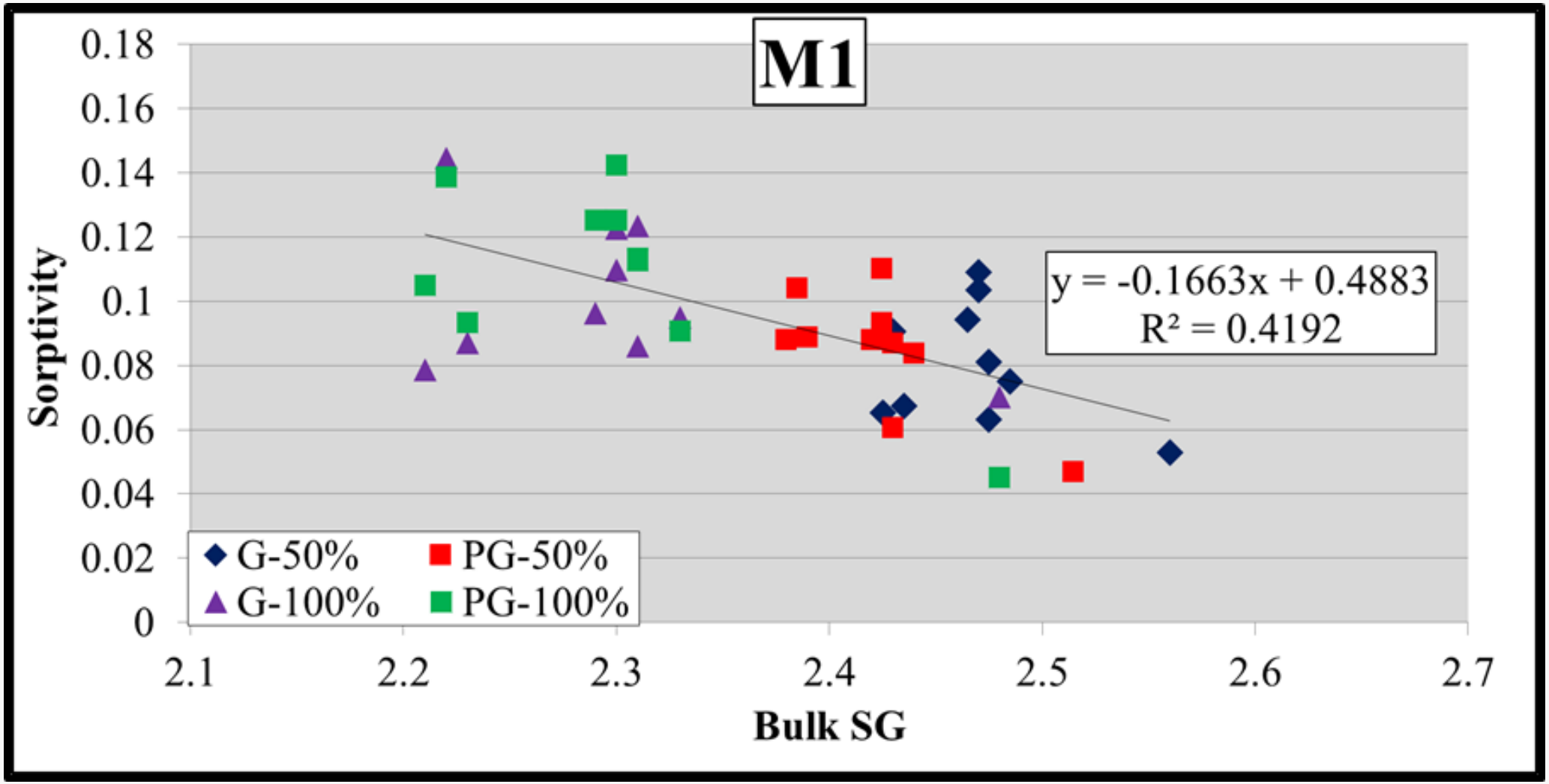
Sorptivity vs. Absorption - M1



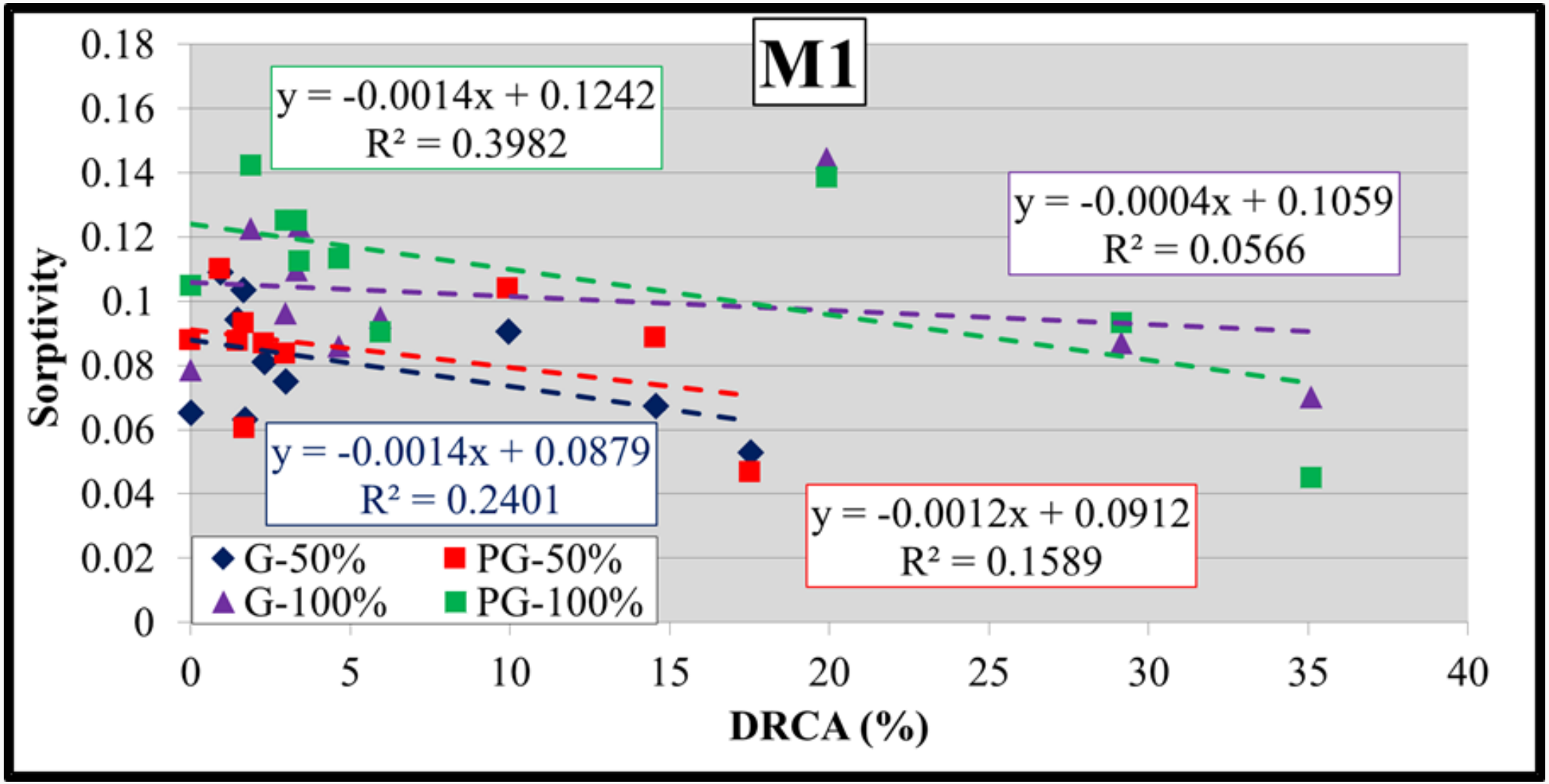
Sorptivity vs. Bulk SG - M1



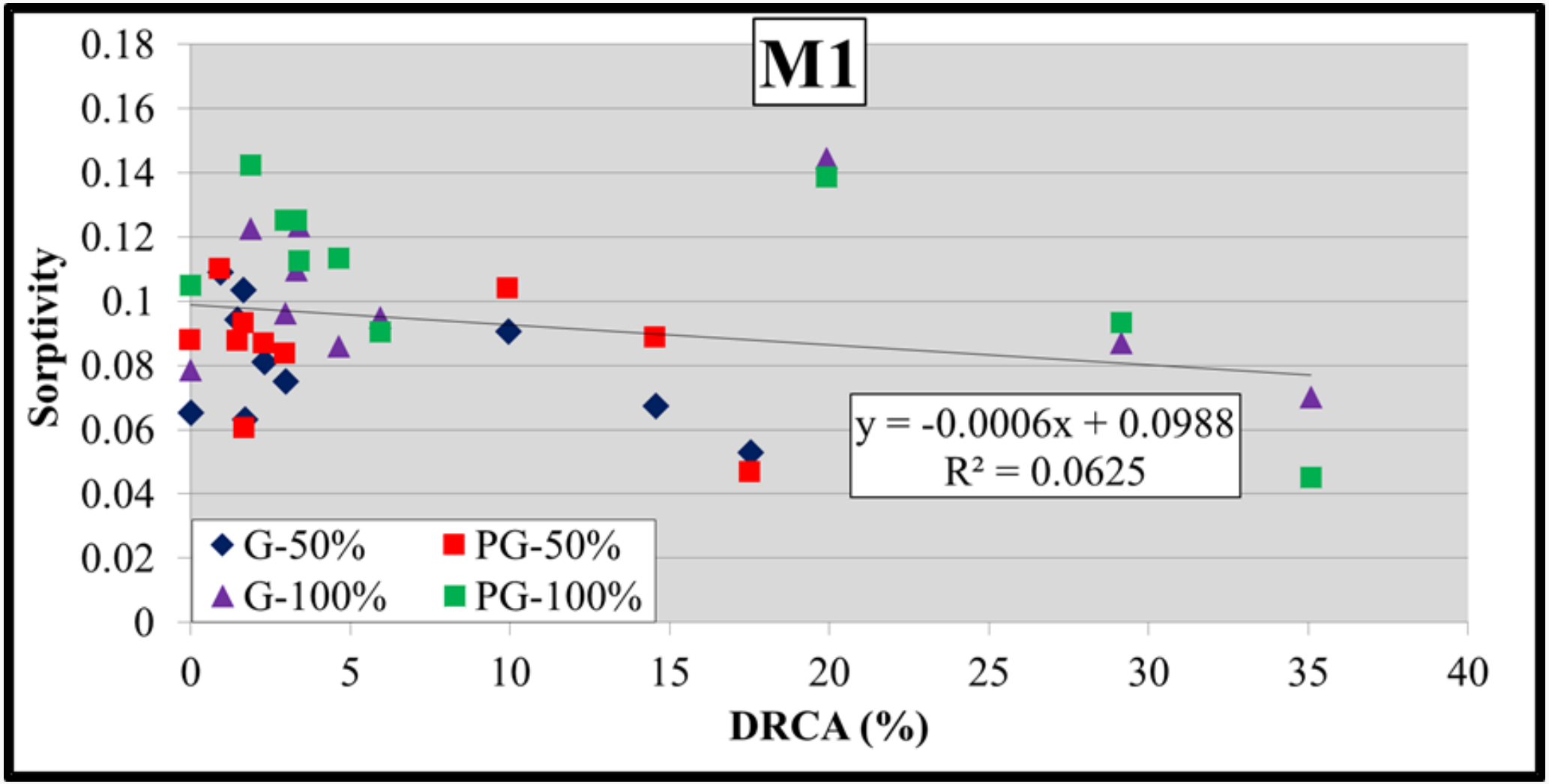
Sorptivity vs. Bulk SG - M1



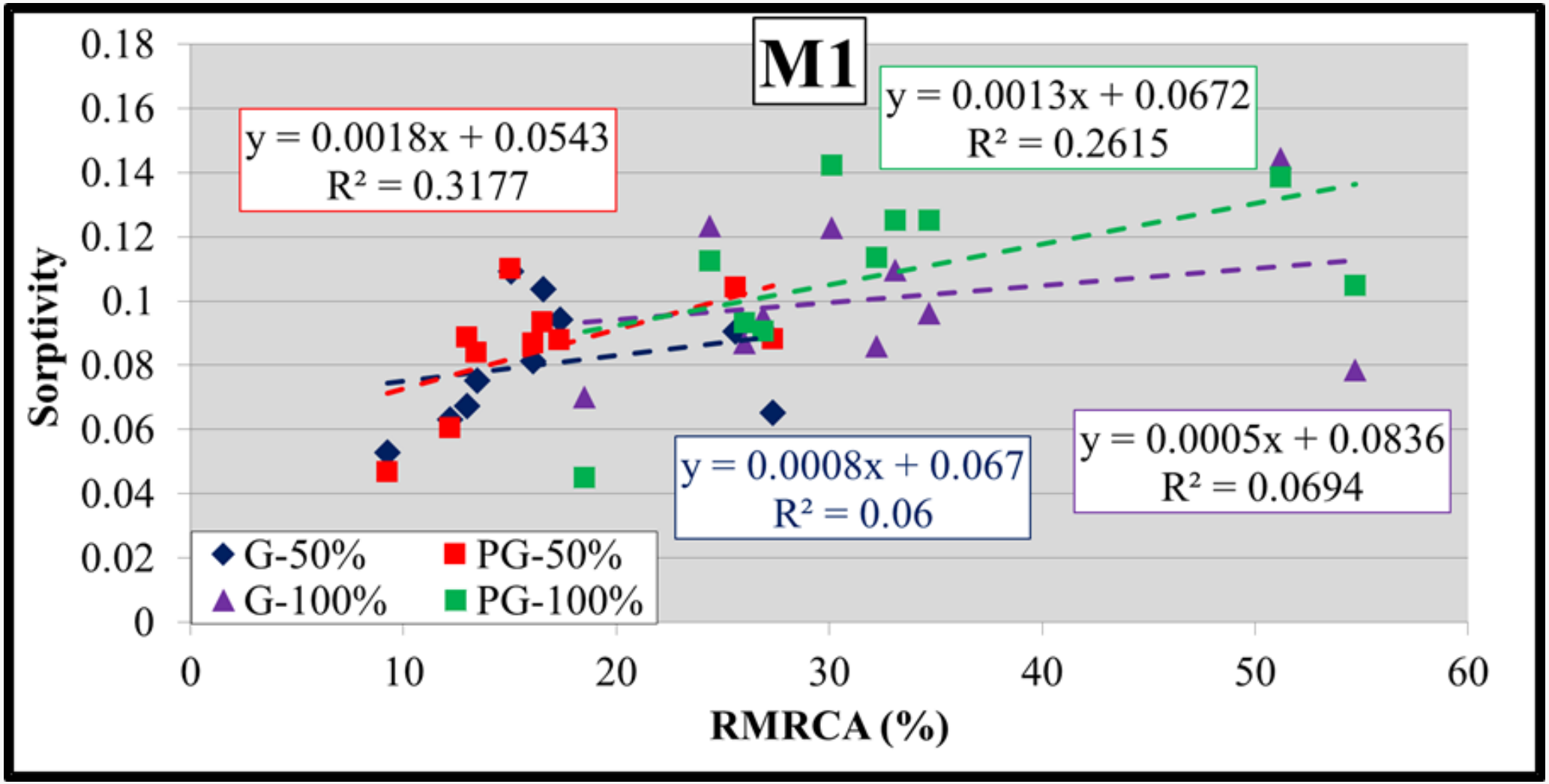
Sorptivity vs. DRCA - M1



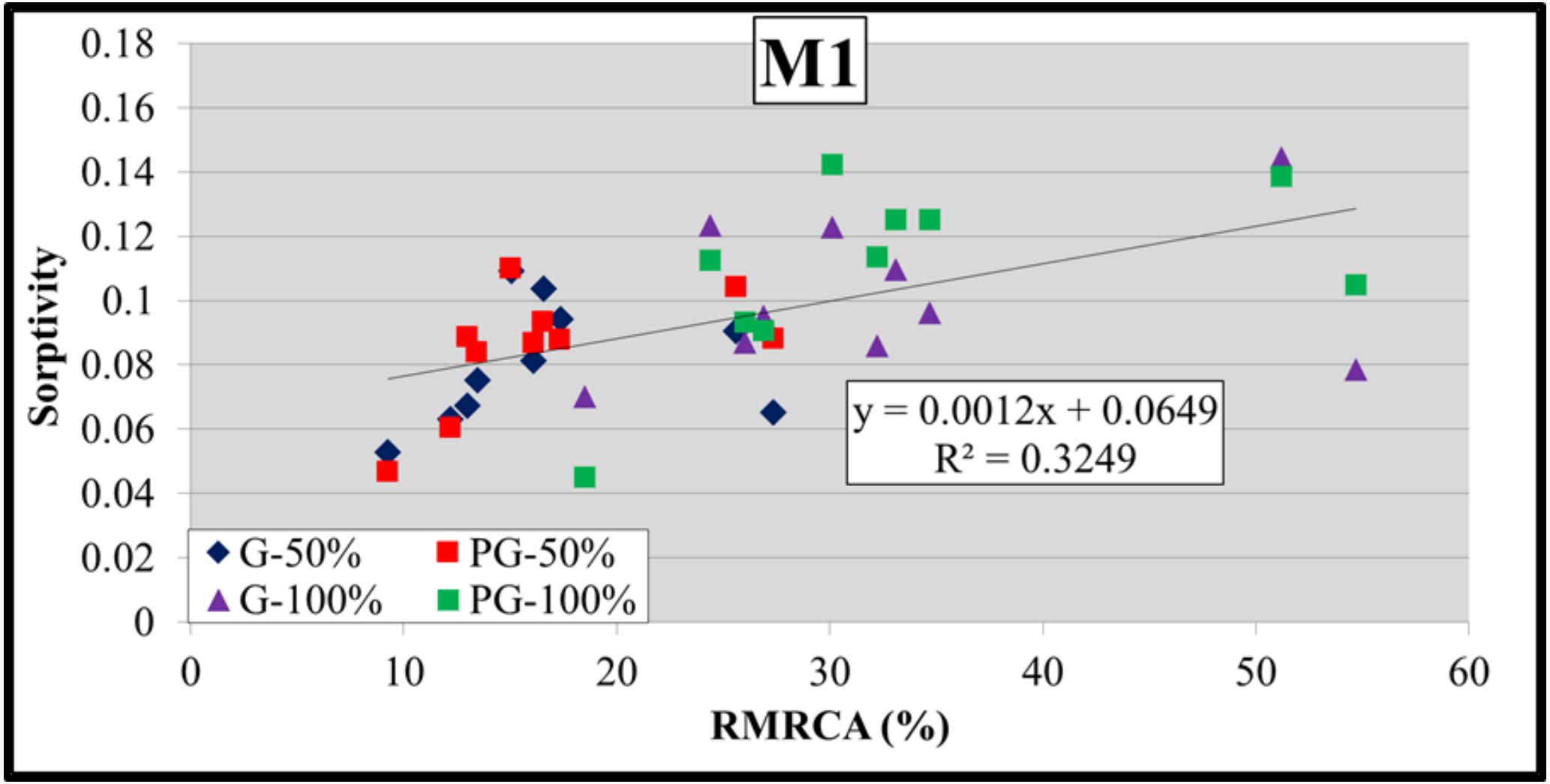
Sorptivity vs. DRCA - M1



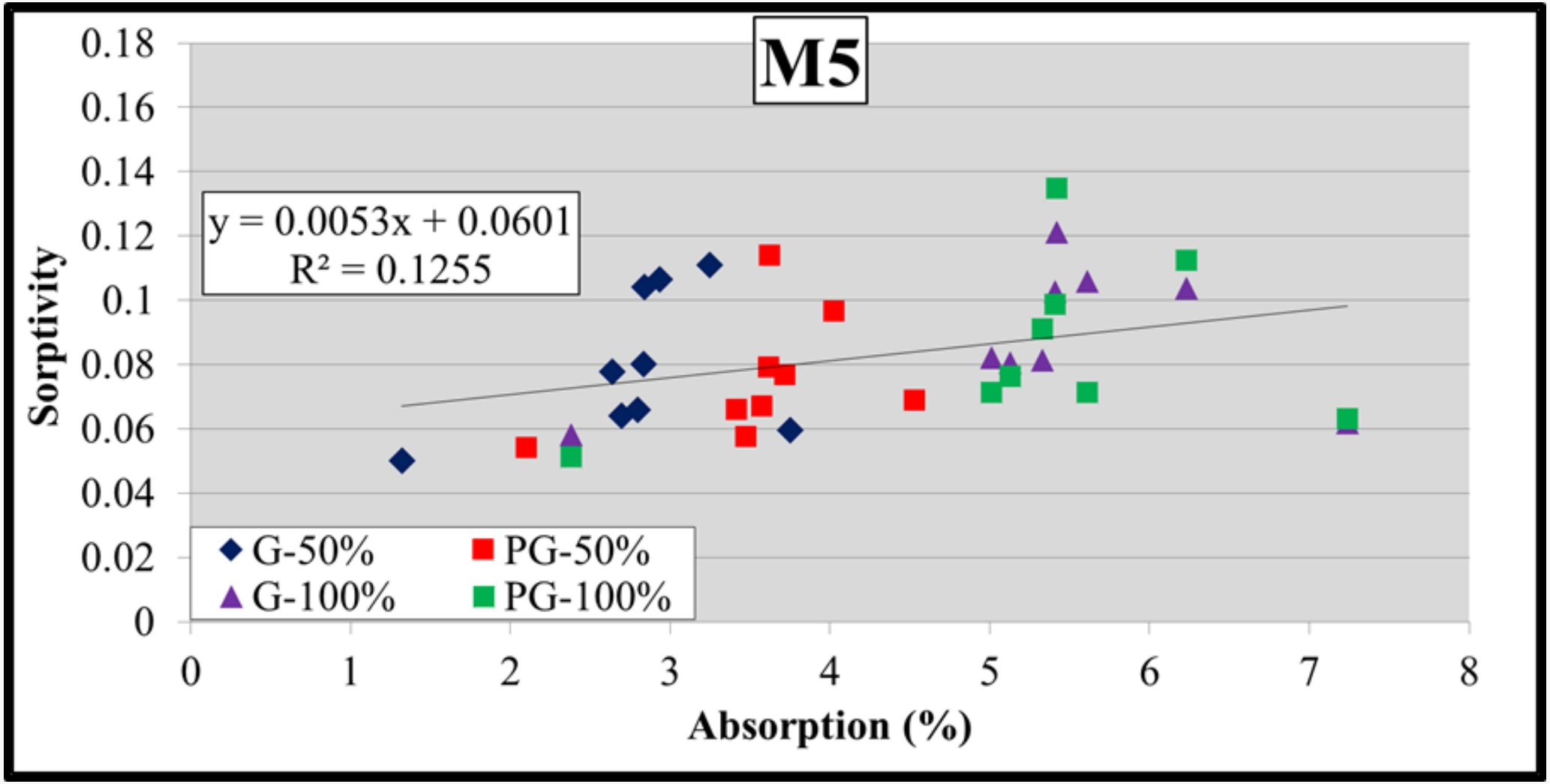
Sorptivity vs. RMRCA- M1



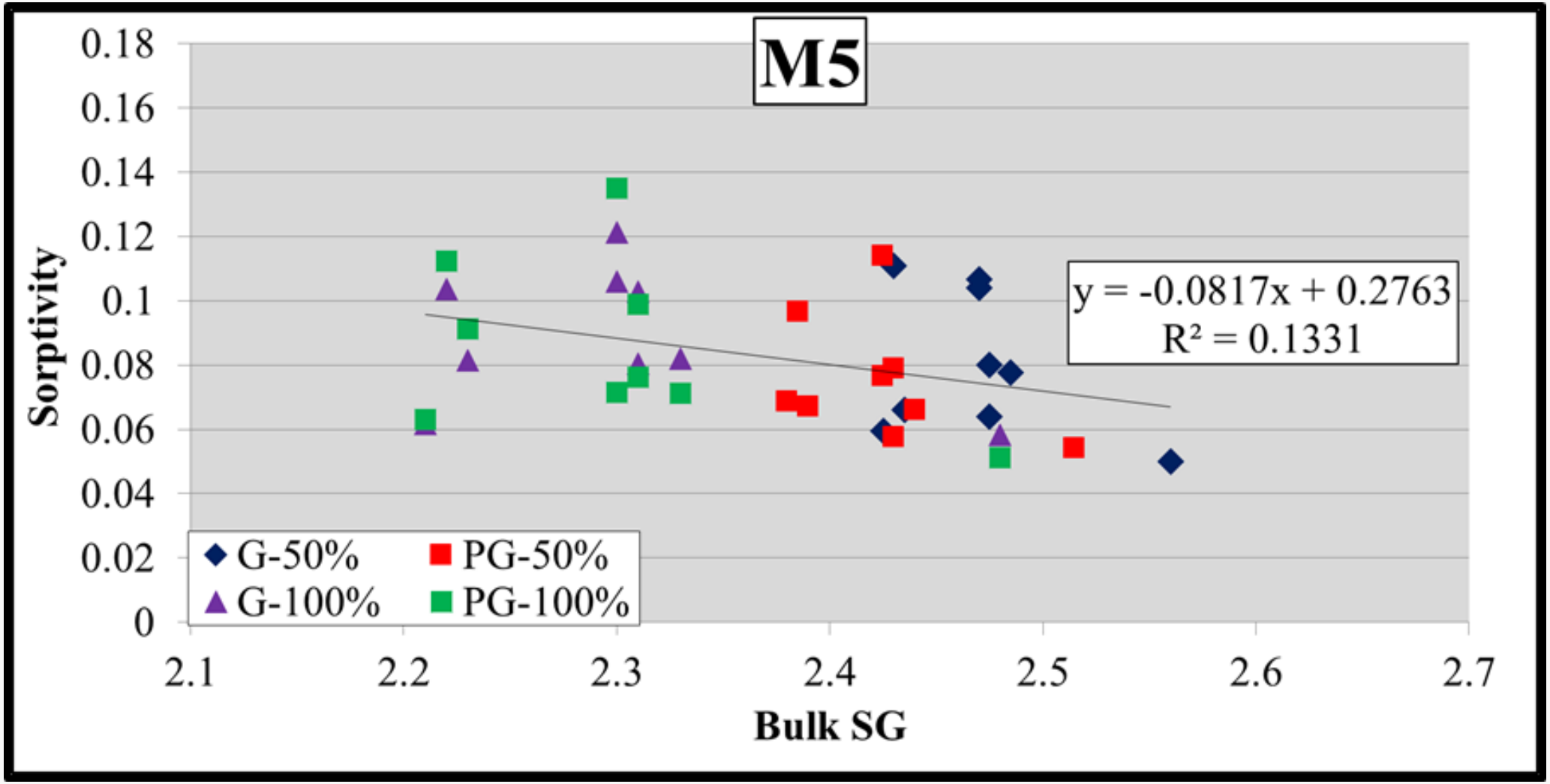
Sorptivity vs. RMRCA- M1



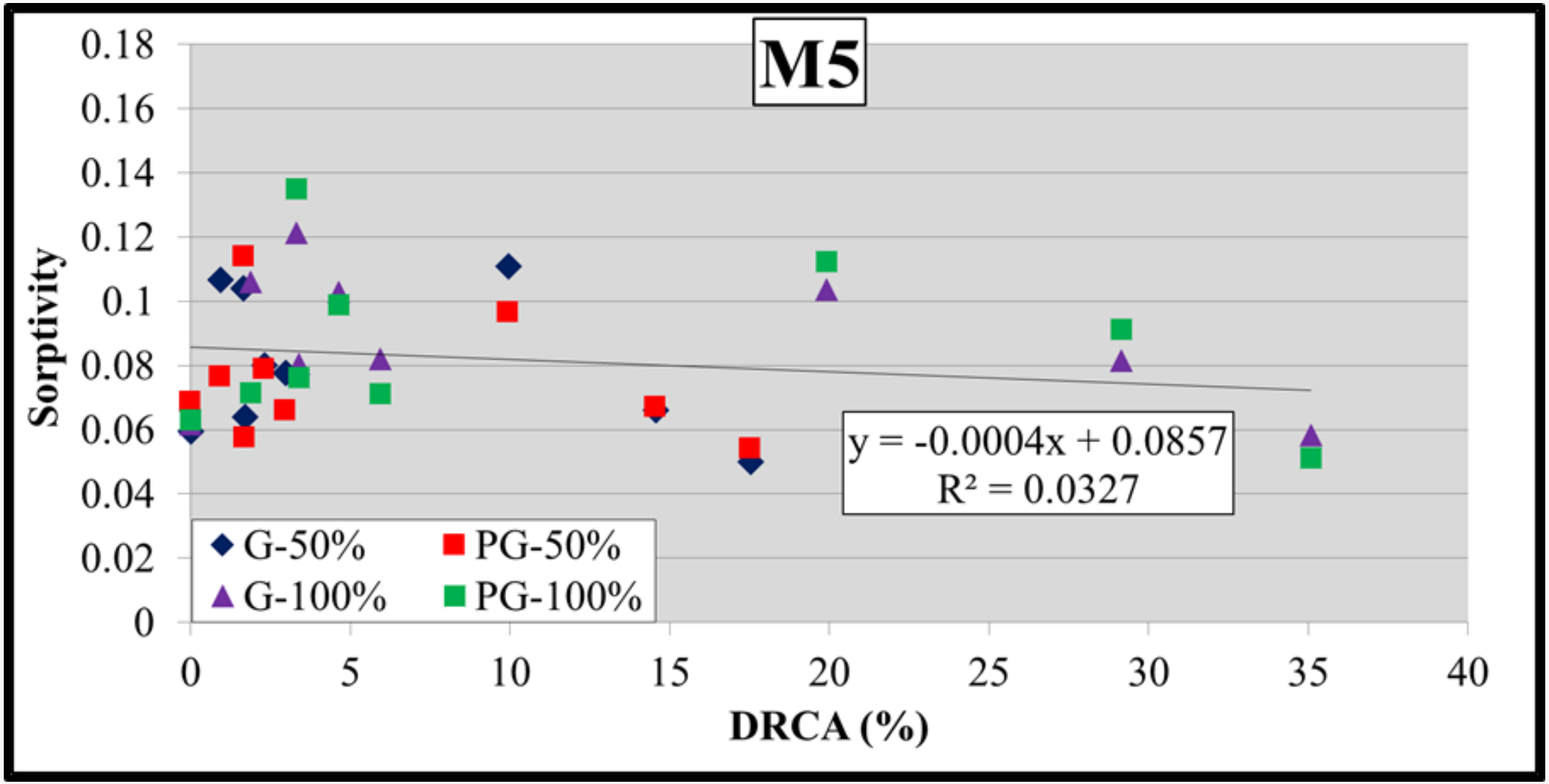
Sorptivity vs. Absorption – M5



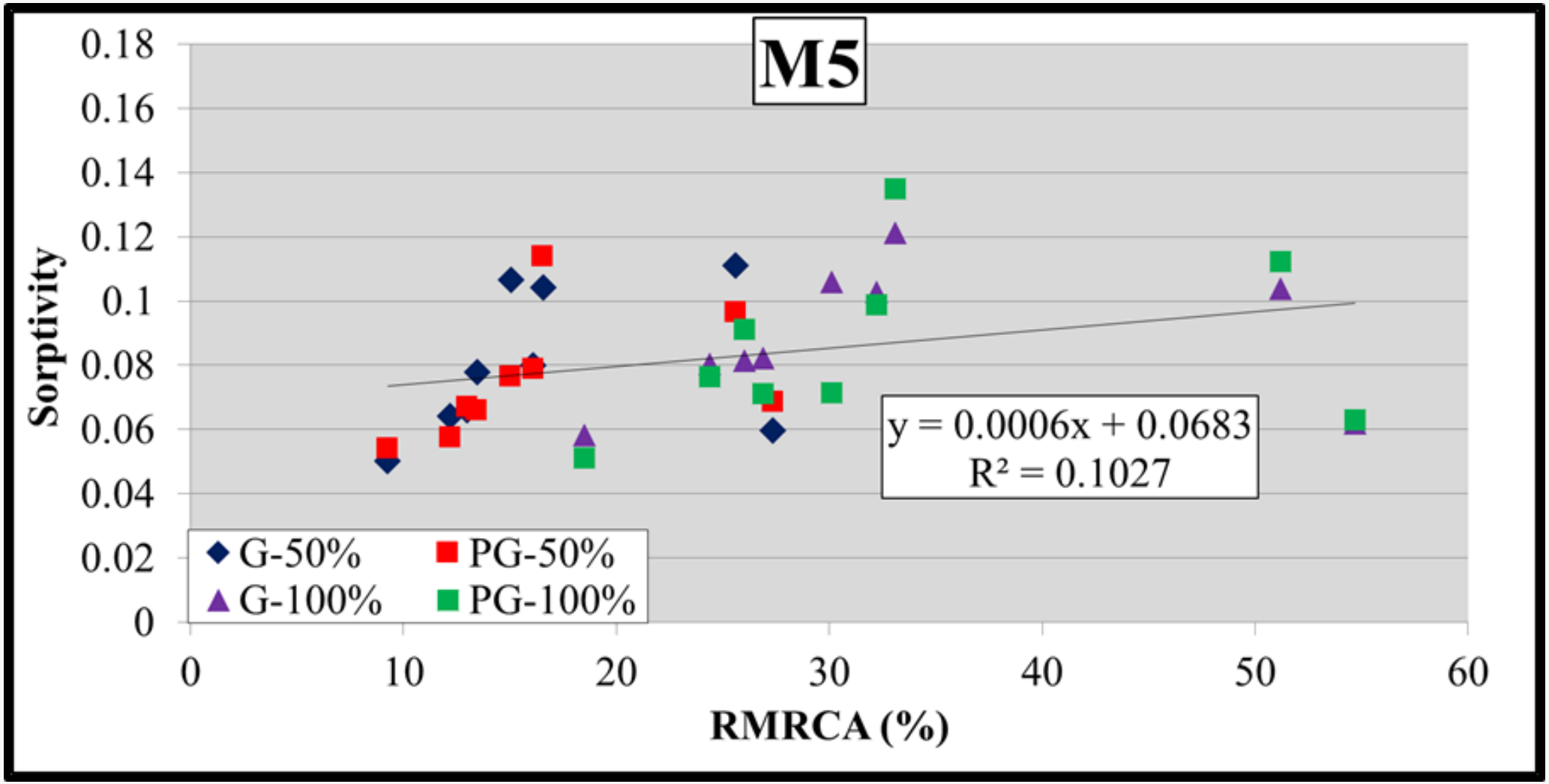
Sorptivity vs. Bulk SG – M5



Sorptivity vs. DRCA – M5



Sorptivity vs. RMRCA- M5



Conclusions

- The variability of RCA properties available for purchase was reasonably large for gradation (many sold as road base or for other applications other than concrete making) and for deleterious material (ranging from 1.87% to 35.1% over the data set studied).
- The specific gravity of the RCA samples was also variable, ranging from 2.1 to 2.5
- The absorption of the RCA data set ranged from approximately to 10%, and it was linearly related to the RCA specific gravity.
- The contents of the deleterious material made a significant impact. A heavy presence of brick results in a high absorption and Sorptivity, low bulk SG and RM_{RCA}; A heavy presence of asphalt results in a low absorption and Sorptivity, high bulk SG and RM_{RCA}

Conclusions

- Residual mortar was high variable ranging between 18.5% to 63.6%, sharing a weak linear relationship with absorption, bulk SG, and D_{RCA}
- Sorptivity of PG mixes (M1 & M5) had stronger linear relationships with other parameters than G mixes (M1 & M5) as a result of PG's properties being closer to that of RCA's.
- Sorptivity of M1 mixes had stronger linear relationships with other parameters than M5 mixes as a result of M5 mixes having less coarse aggregate
- Sorptivity of M1 and M5 mixes shared no linear relationships with D_{RCA}

THE UNIVERSITY OF TEXAS AT TYLER

College of Engineering

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