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Mechanical Behavior of Recycled Concrete Aggregates (RCA) for Improved Sustainability of Reinforced Concrete Building Structures

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Environmental Considerations of Recycled Concrete Aggregates (RCA) for Improved Sustainability of Reinforced Concrete Building Structures

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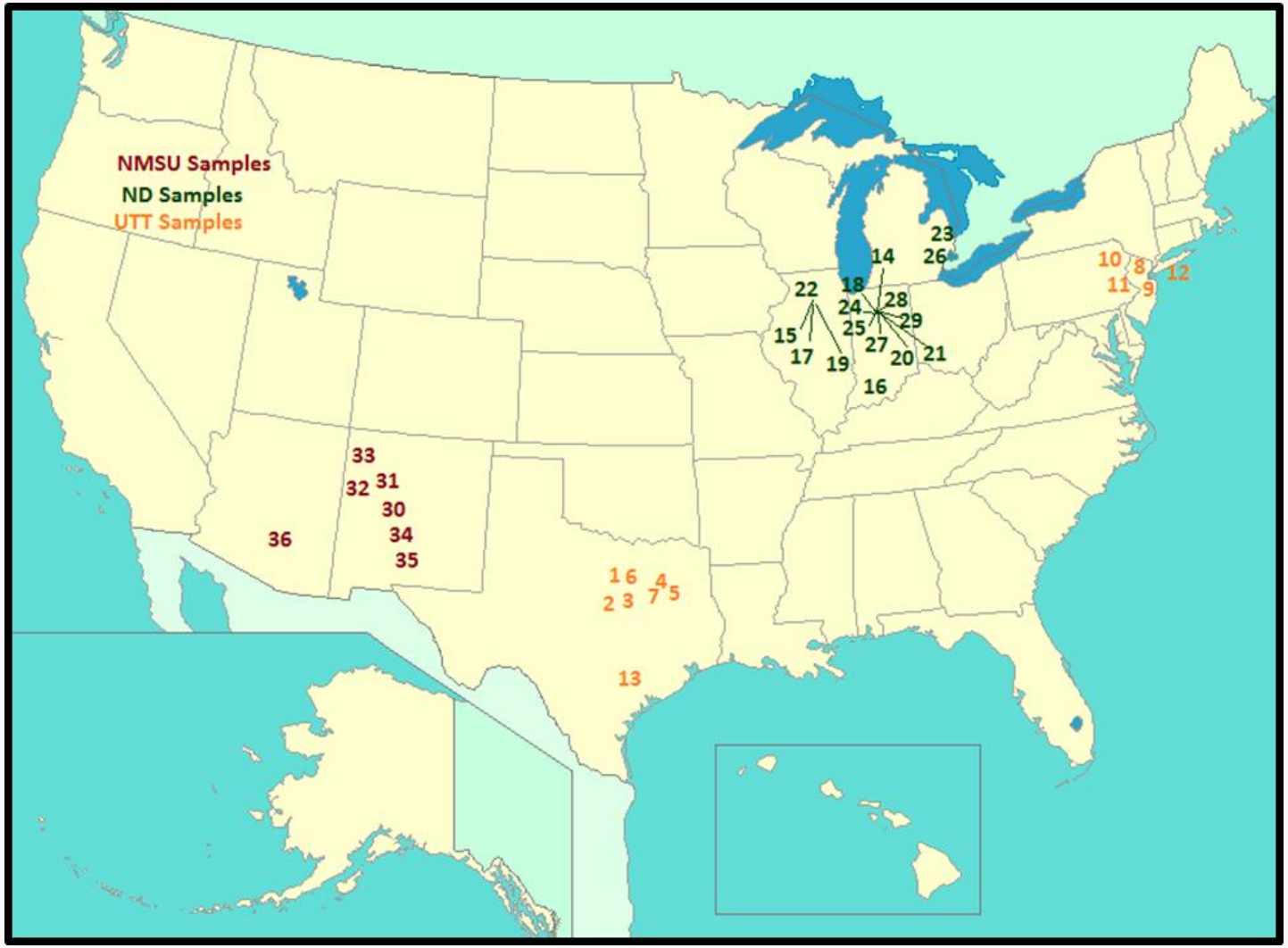
Outline

- RCA Sample Collection
- Sample & Target Gradations
- Natural Aggregate (NA) & Recycled Concrete Aggregate (RCA) Properties
- Mix Designs
- 28-Day Compressive Strength Results
- Relationship between Theoretical Values and Measured Values

Collected Samples



BCL - 3” (TX)

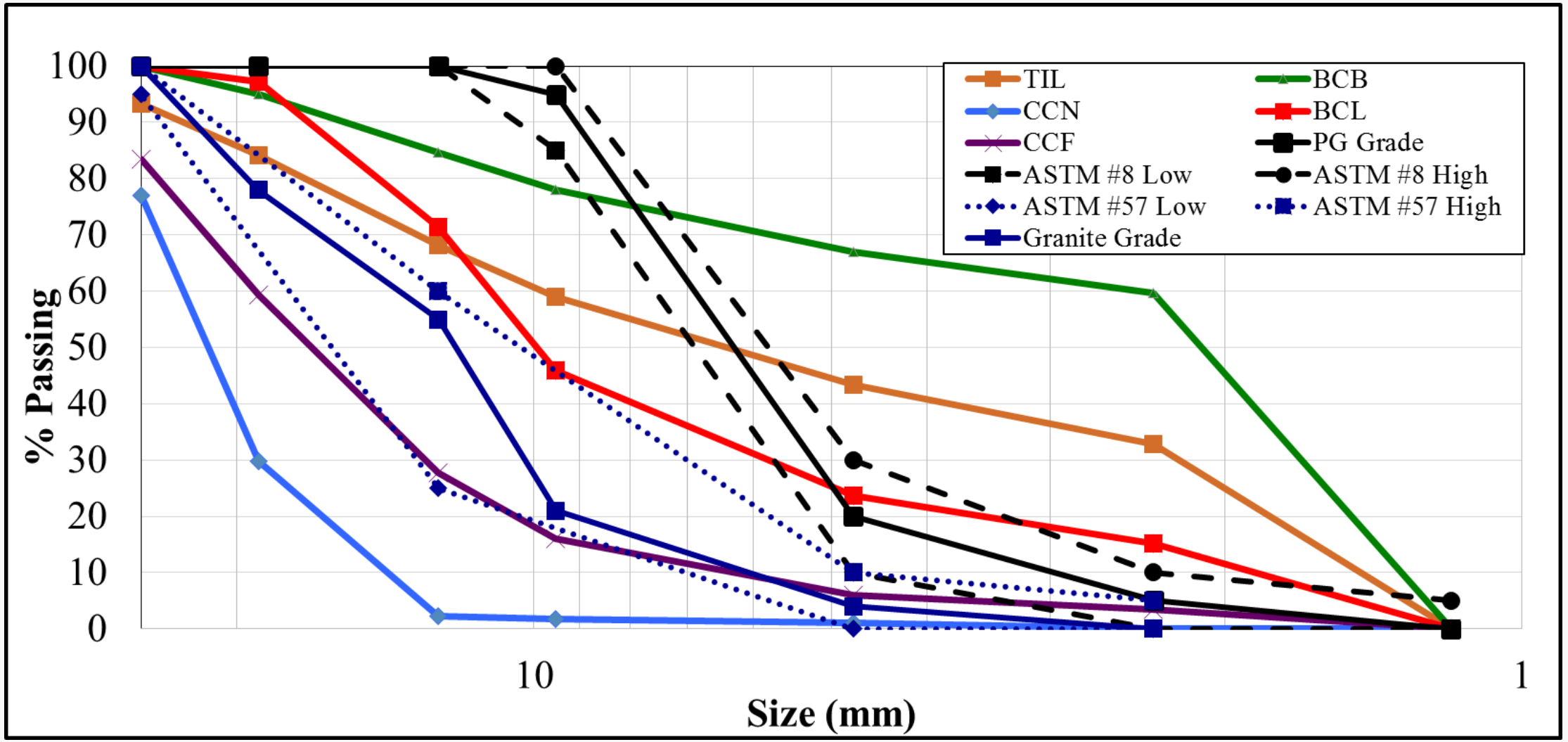
BCB - Base (TX)

CCF - 1.5” Minus (PA)

CCN - 1.5” to 0.375” Minus (PA)

TIL - 1.5” Minus (NJ)

Gradations


100
90
80
70
60
50
40
30
20
10
0
% Passing
10
1
Size (mm)
TIL
CCN
CCF
ASTM #8 Low
ASTM #57 Low
Granite Grade
BCB
BCL
PG Grade
ASTM #8 High
ASTM #57 High

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

State of Origin	Sample	Type	Absorption	Bulk SG	Bulk SSD	Apparent SG	DRCA (%)
NJ	TIL	RCA	5.41	2.31	2.43	2.64	4.63
PA	CCF	RCA	5.01	2.33	2.45	2.64	5.95
PA	CCN	RCA	5.02	2.33	2.44	2.63	10.33
TX	BCB	RCA	5.95	2.28	2.42	2.64	2.29
TX	BCL	RCA	5.52	2.29	2.42	2.62	2.96
TX	PG	NA	1.83	2.55	2.60	2.68	N/A
TX	Sand	NA	1.00	2.62	2.65	2.69	N/A

NA and RCA Properties

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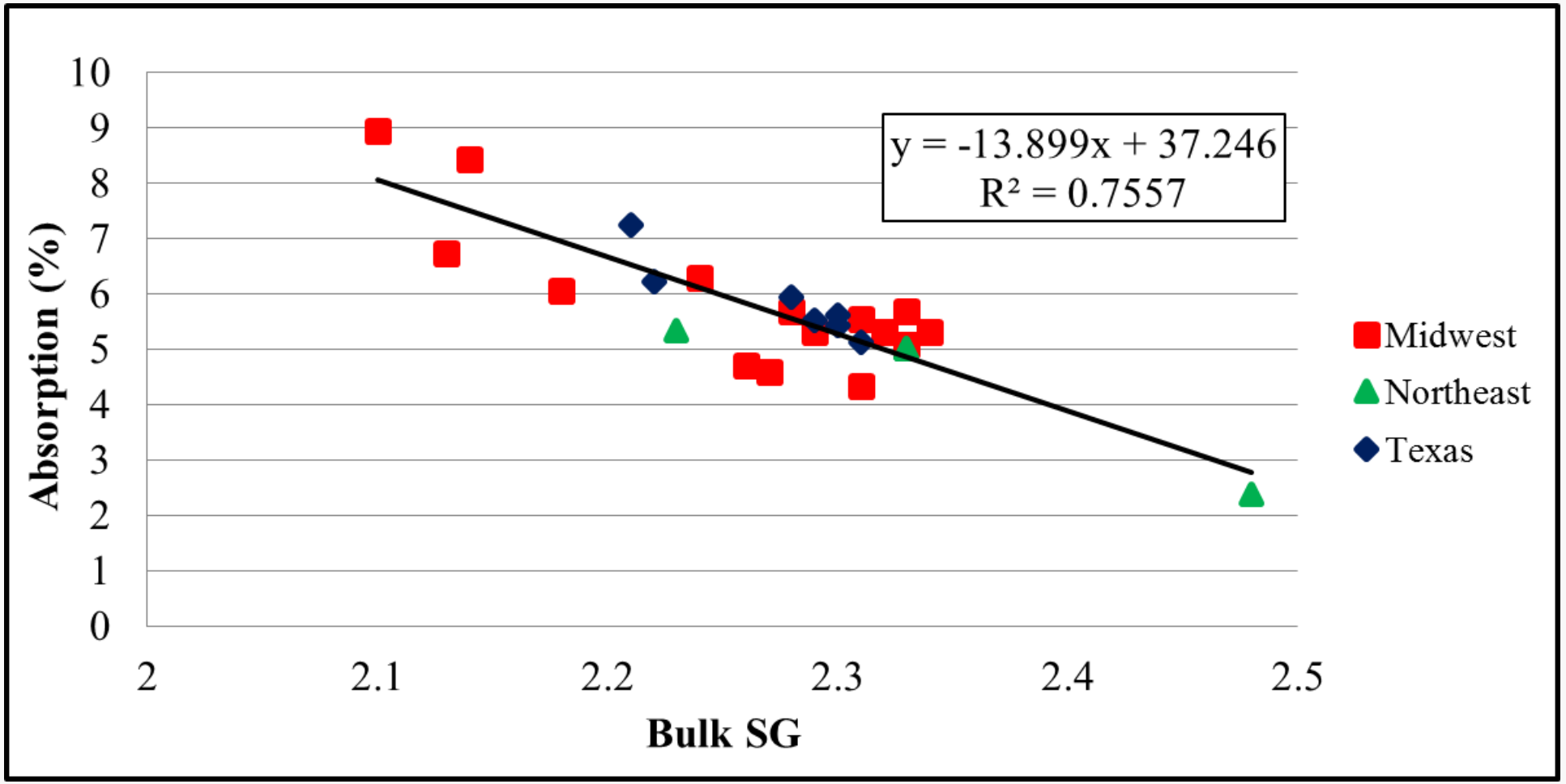
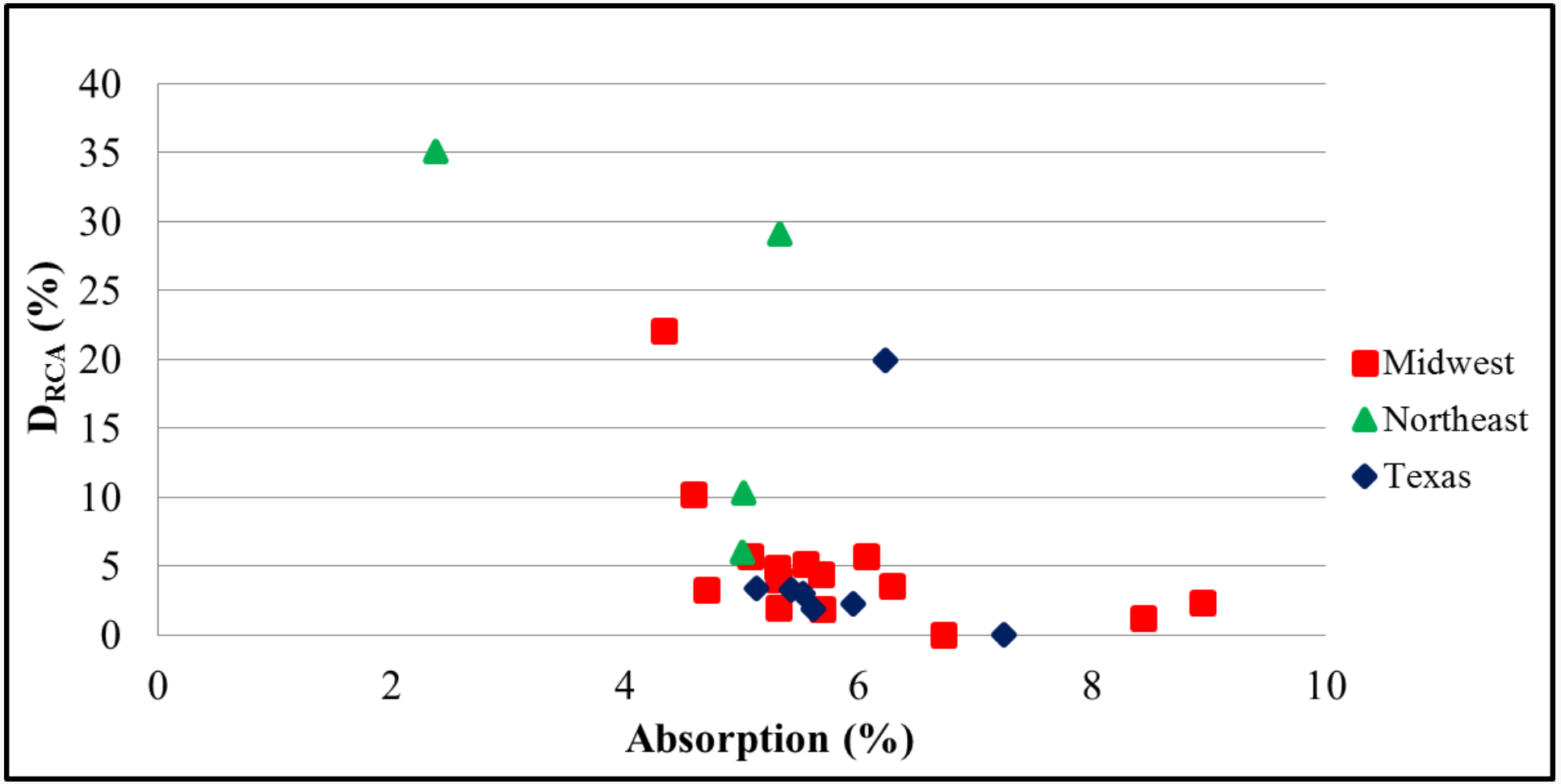
TX	Sand	NA	1.00	2.62	2.65	2.69	N/A

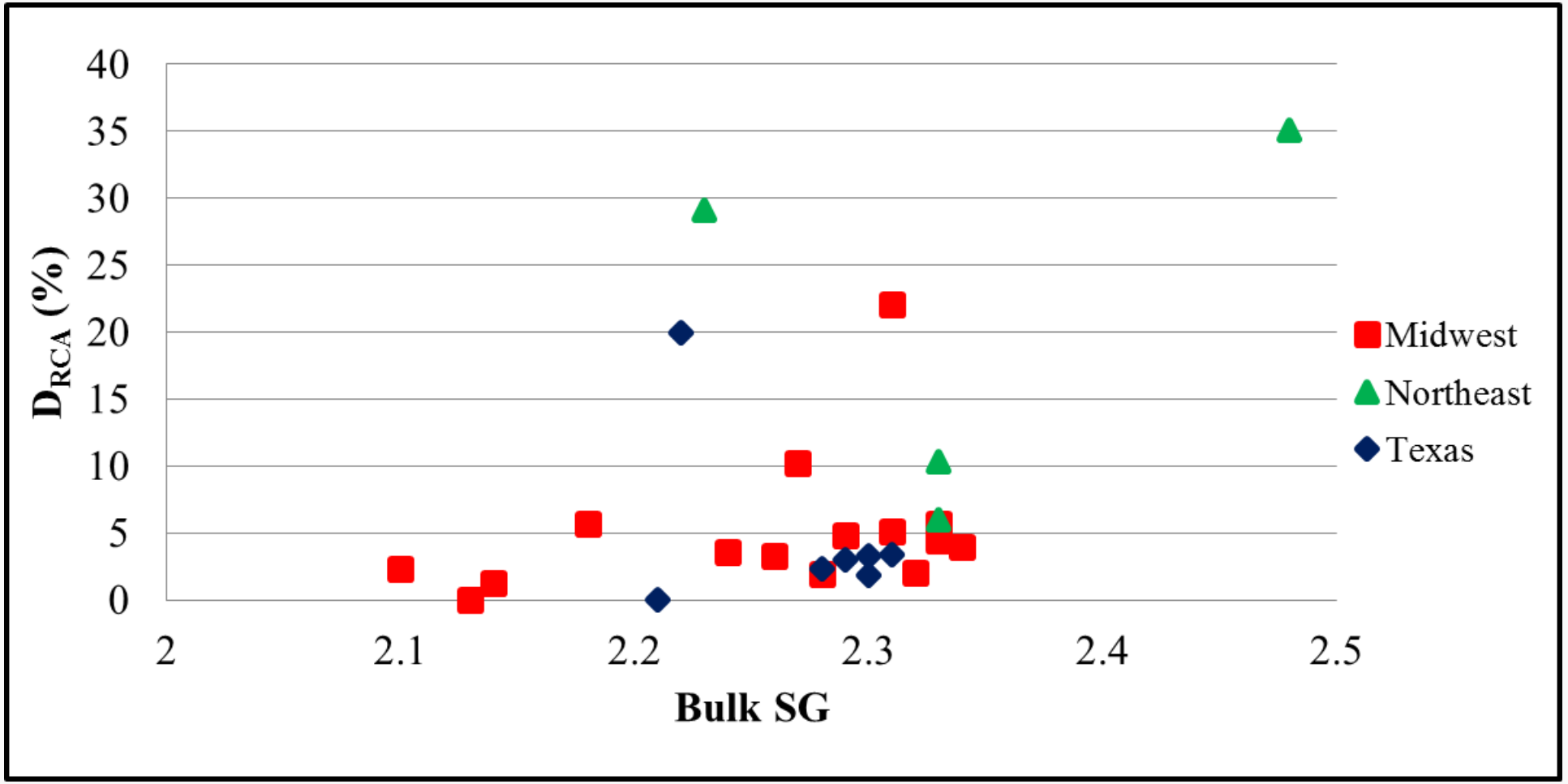
Absorption vs. Specific Gravity



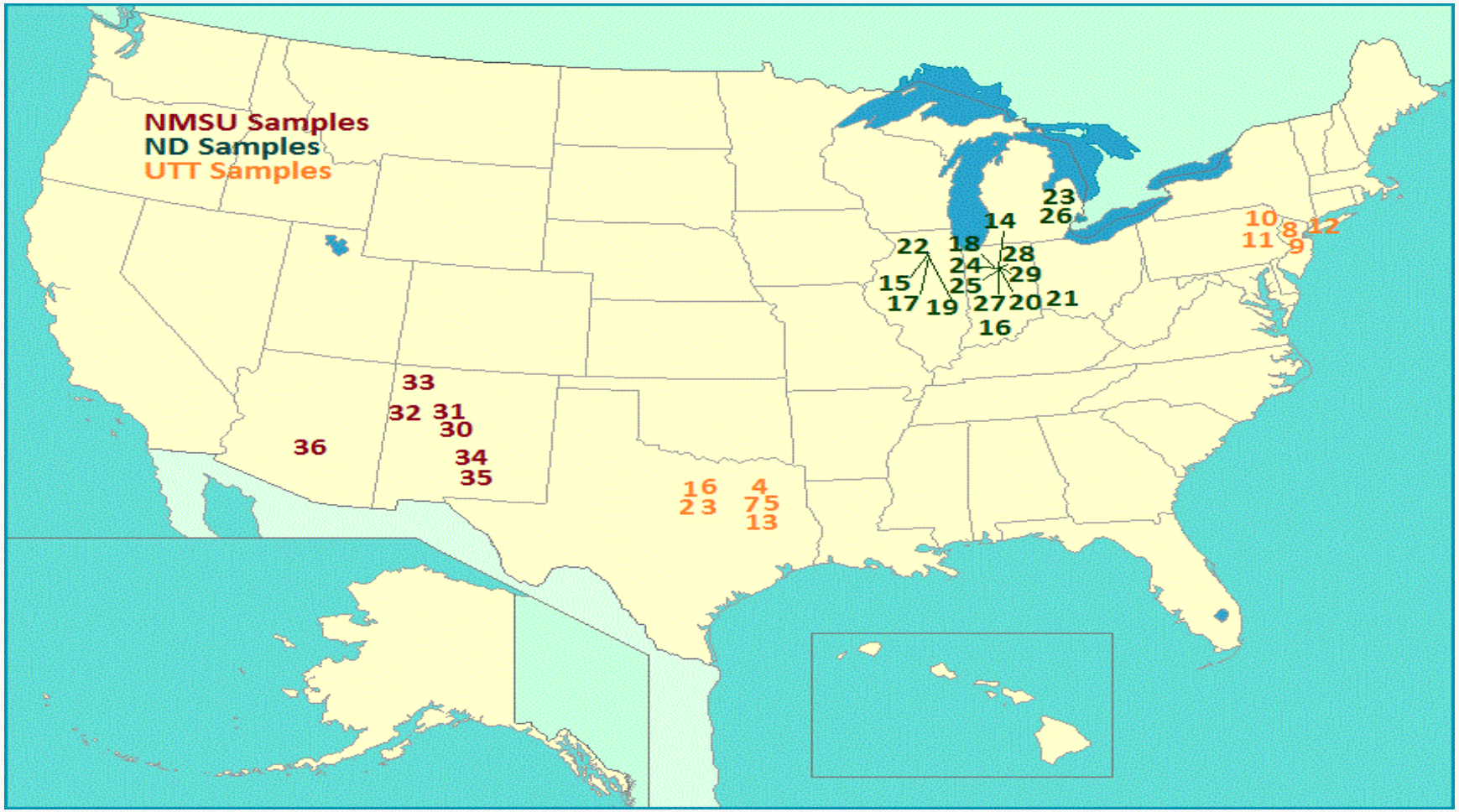
Deleterious Material (DRCA) vs Absorption



DRCA vs Bulk Specific Gravity



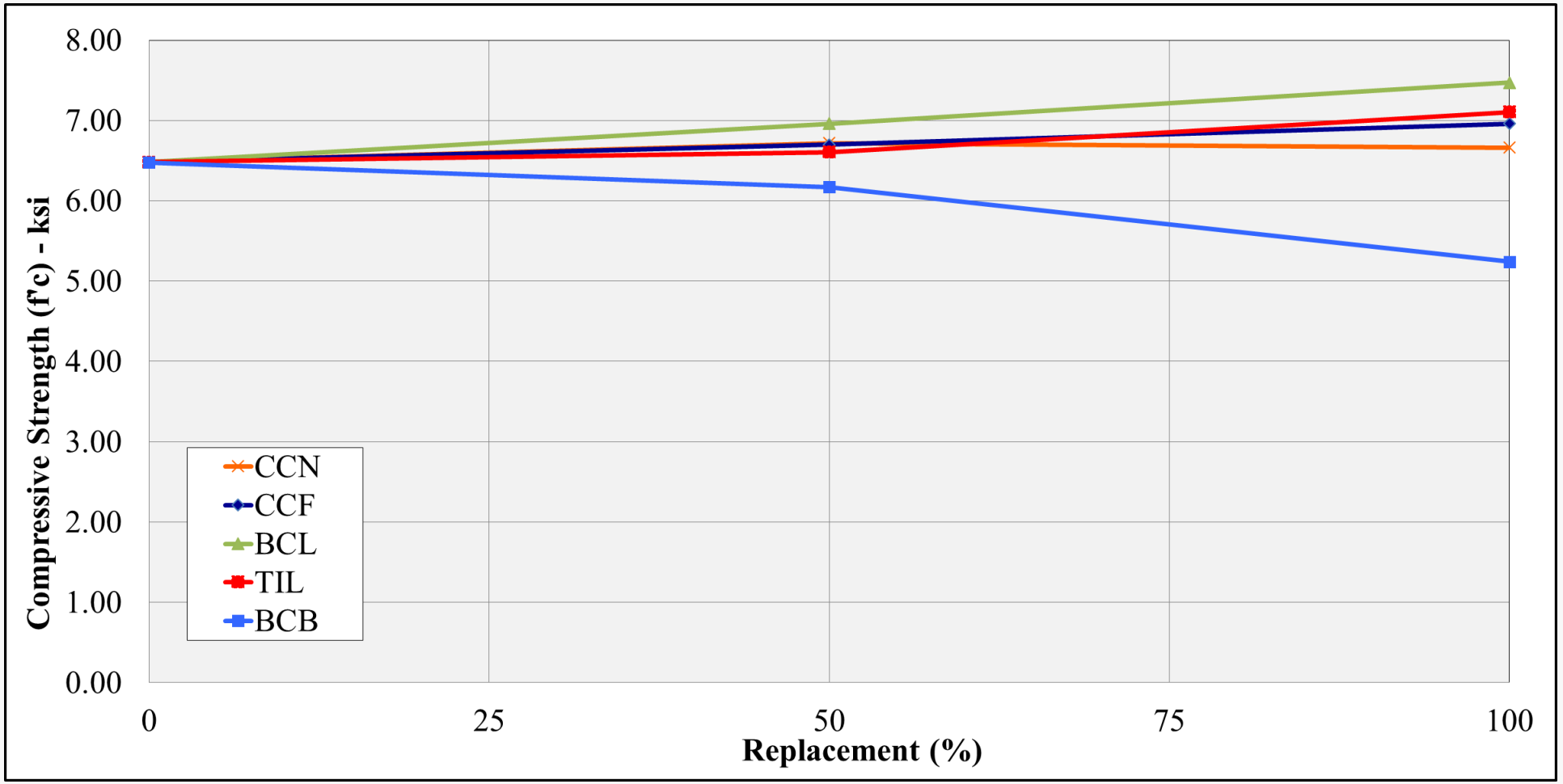
Collected Samples



Mix Designs

PG Graded M1 Mixes							
Sample	Replacement (%)	PS 1466 (mL)	Cement (lbs)	CA Added (lbs)	FA Added (lbs)	Water Added (lbs)	Weight in Mixer (lbs)
PG	0	7.79	4.40	11.80	9.96	0.553	26.7
BCB	50	7.89	4.45	12.30	9.94	0.000	26.7
	100	7.99	4.51	12.02	10.11	0.098	26.7
BCL	50	7.89	4.44	11.90	10.10	0.260	26.7
	100	7.99	4.51	11.85	10.25	0.093	26.7
TIL	50	7.89	4.45	11.80	10.15	0.30	26.7
	100	7.99	4.50	11.90	10.25	0.049	26.7
CCN	50	7.89	4.45	11.95	9.98	0.297	26.7
	100	7.99	4.50	12.07	10.04	0.106	26.7
CCF	50	7.89	4.44	11.86	10.05	0.357	26.7
	100	7.99	4.49	11.85	10.20	0.159	26.7

28 Day Compressive Strength



Prediction Equation

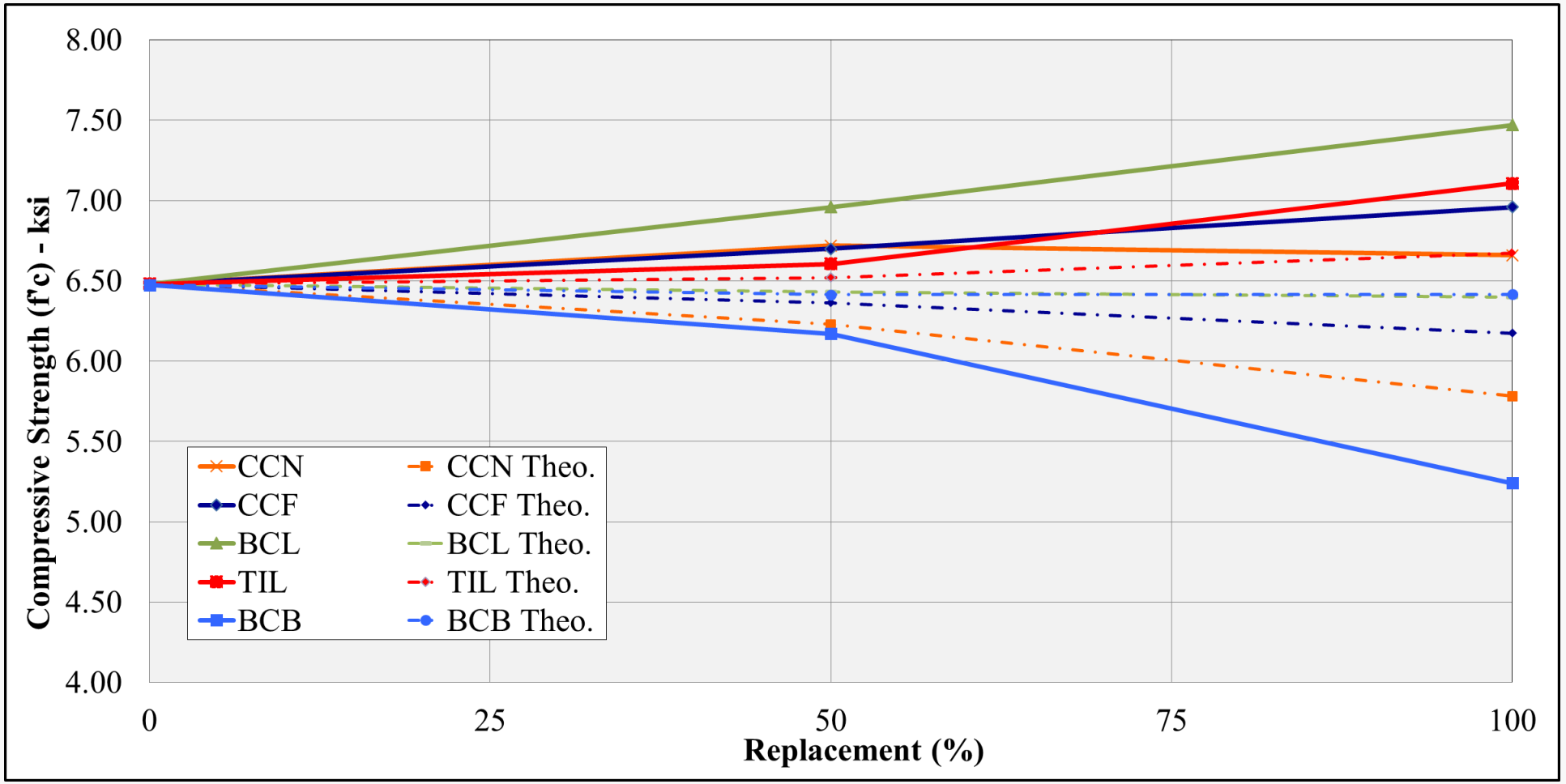
$$f'c,RCA/f'c,NA = \beta_{f1} + \beta_{f2} \times + \beta_{f3} \times D + \beta_{f4} \times R$$

Mean Value of Unnormalized Regression Coefficients	βf_1	1.0241	95% Confidence Interval For Unnormalized Regression Coefficients	βf_1	[1.0026, 1.0456]
	βf_2	-0.0241		βf_2	[-0.0300 ,-0.0182]
	βf_3	-0.0138		βf_3	[-0.0172, -0.0104]
	βf_4	0.0769		βf_4	[0.0299,0.1239]

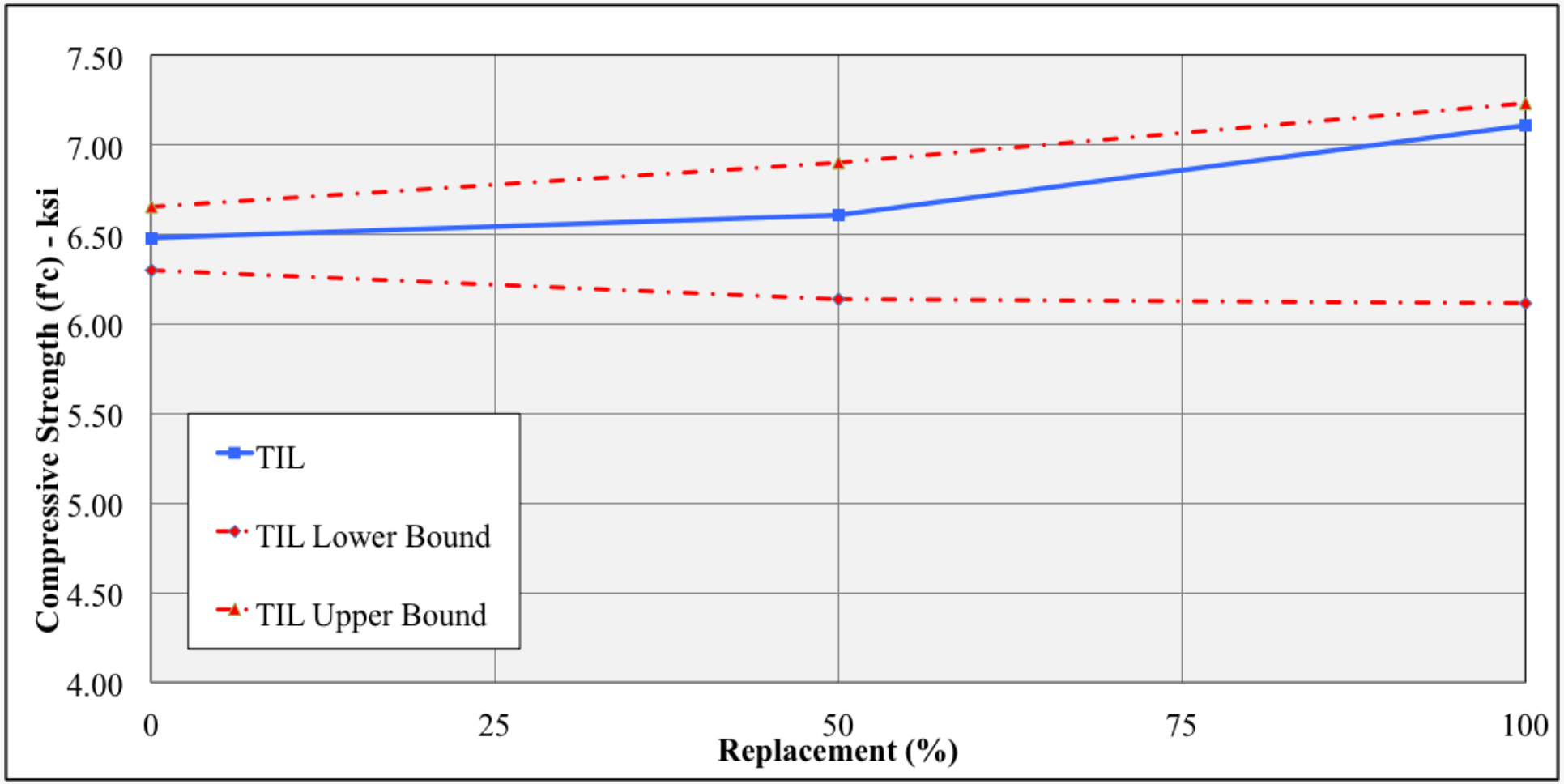
D = Combined deleterious material content of RCA

R = Replacement Percentage

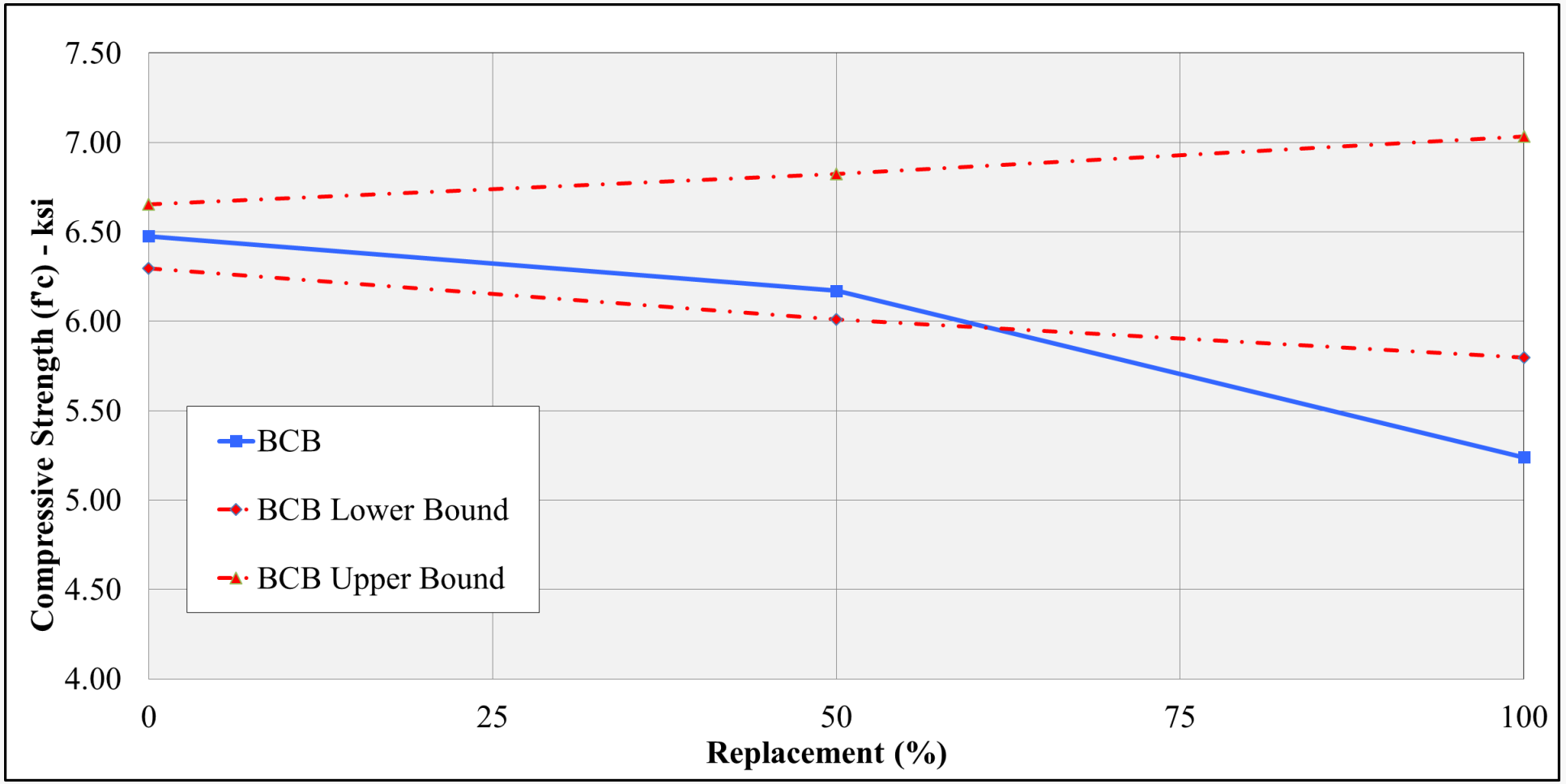
Measured vs. Theoretical



Confidence Intervals



Confidence Intervals



Measured Values vs. Theoretical Values

Sample	Measured f'c at 50% R	Theoretical f'c at 50% R	Percent Difference (%)	Measured f'c at 100% R	Theoritical f'c at 100% R	Percent Difference (%)
BCB	6.17	6.41	-3.89	5.24	6.42	20.19
BCL	6.96	6.43	7.87	7.47	6.40	15.45
CCF	6.70	6.36	5.16	6.96	6.17	11.95
CCN	6.72	6.23	7.57	6.66	5.78	14.11
TIL	6.61	6.52	1.29	7.11	6.67	6.29

Measured Values vs. Theoretical Values

Sample	Measured f'c at 50% R	Theoretical f'c at 50% R	Percent Difference (%)	Measured f'c at 100% R	Theoritical f'c at 100% R	Percent Difference (%)
BCB	6.17	6.41	-3.89	5.24	6.42	-20.19
BCL	6.96	6.43	7.87	7.47	6.40	15.45
CCF	6.70	6.36	5.16	6.96	6.17	11.95
CCN	6.72	6.23	7.57	6.66	5.78	14.11
TIL	6.61	6.52	1.29	7.11	6.67	6.29

RCA's Effect on Strength

Sample	Percent Difference from 0% to 50%	Percent Difference from 0% to 100%
BCB	-4.82	-21.2
BCL	3.71	2.82
CCF	3.42	7.20
CCN	7.22	14.3
TIL	2.00	9.29

Conclusions

- Quality concrete can be made with RCA following the DVR method. The strengths of the mixes with 50% RCA replacement differed from their NA counterparts by approximately ± 10%; for 100% RCA replacement the difference was ± 20%.
- A model created to predict the strength of RCA concrete mixes based on the absorption and DRCA of a subset of all available data needs further development – this is future work planned by the project team.

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.

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