

Improve Material Inputs into Mechanistic Design Properties for Reclaimed HMA & Recycled Concrete Aggregate (RCA) Roadways

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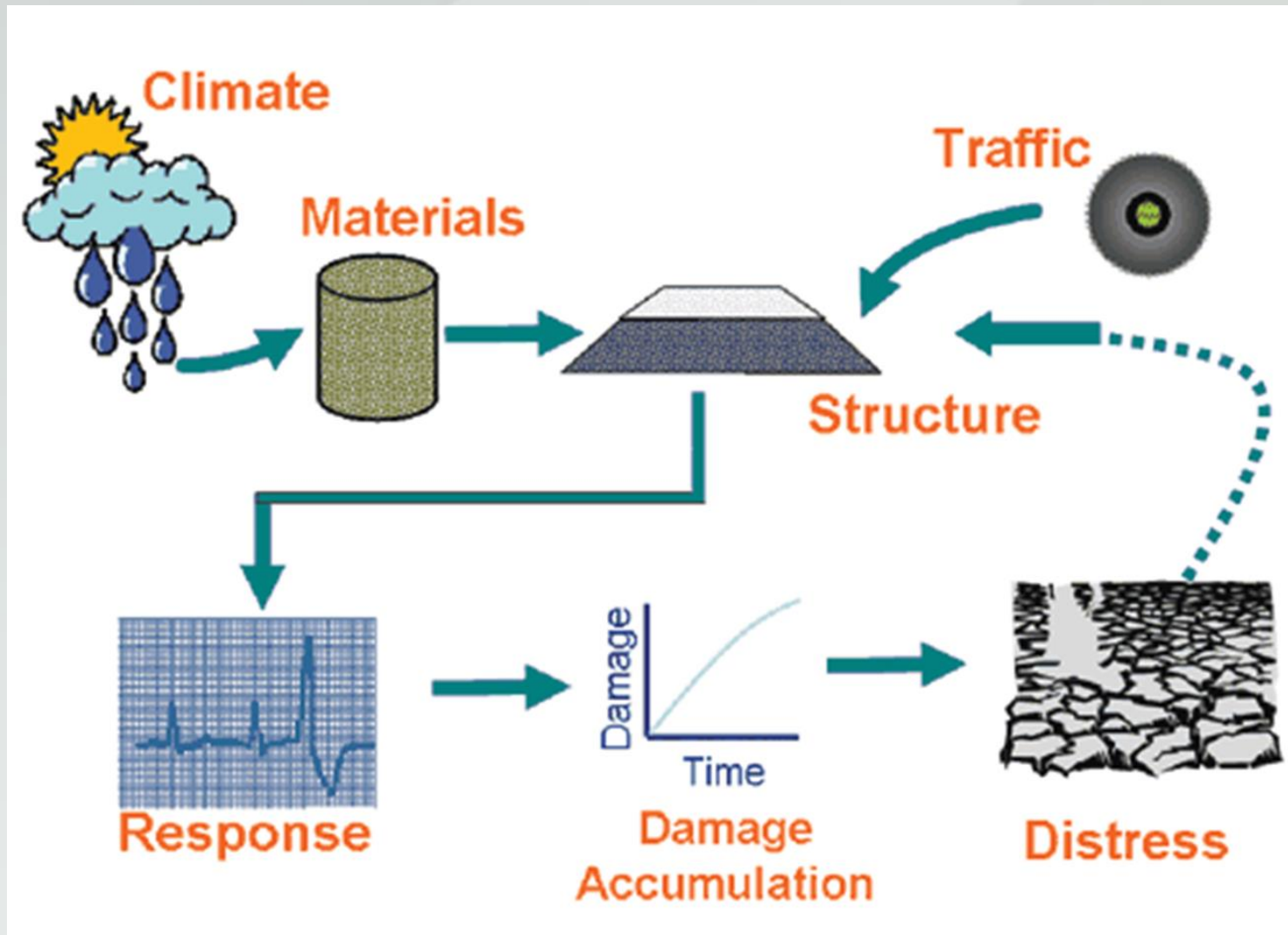
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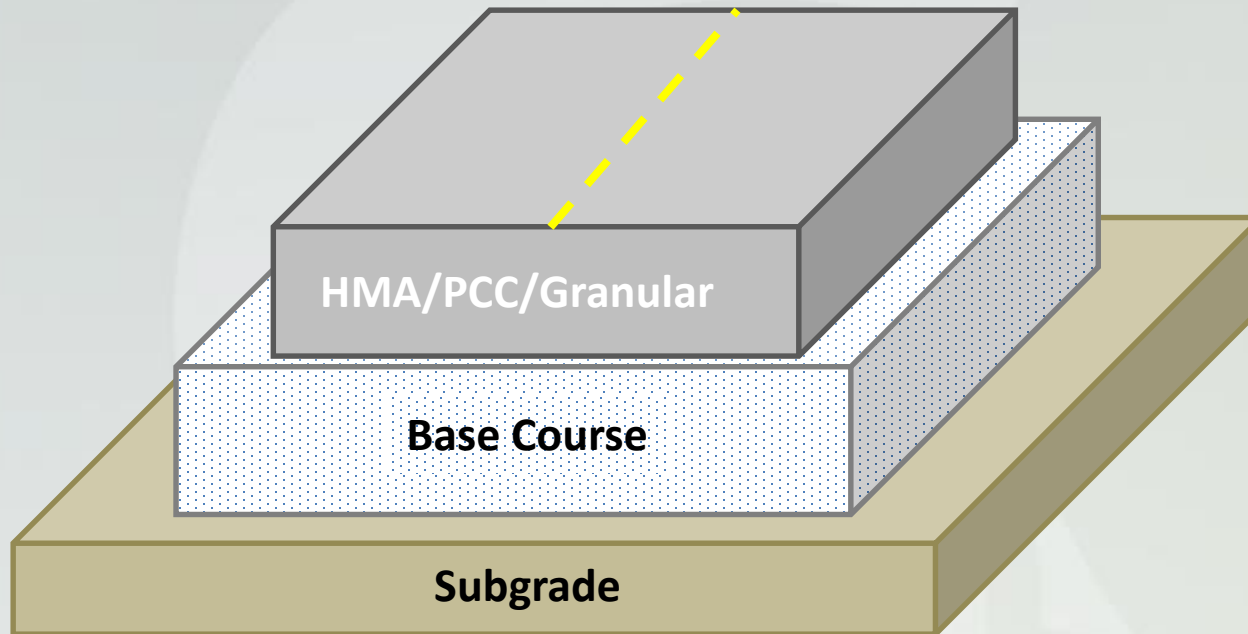
Michigan State University

Sep 3, 2020

MEPDG Analysis Process

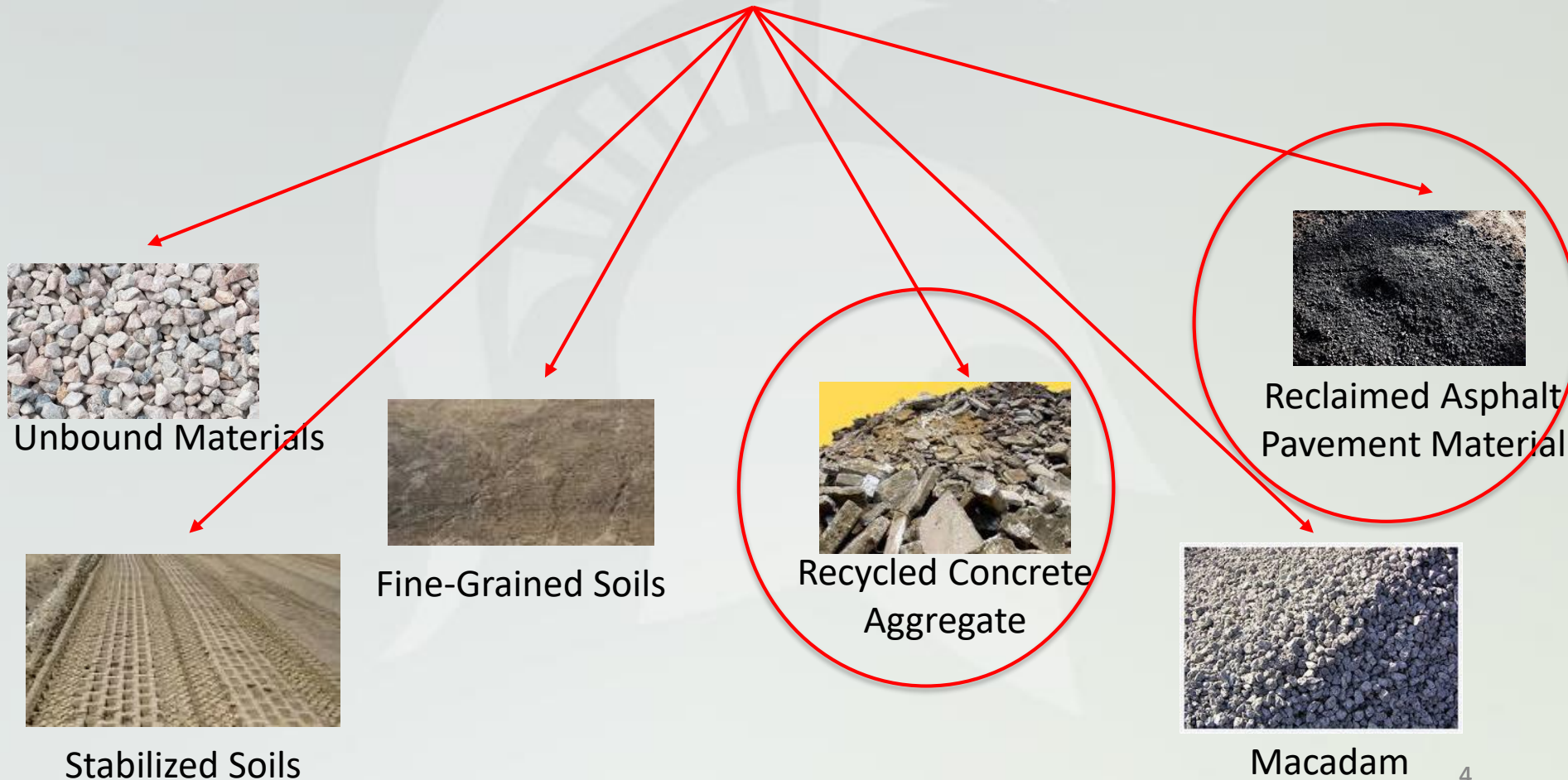


MATERIALS INPUT



MATERIALS INPUT

Range of Materials



MATERIALS INPUT FOR PAVEMET ME

Strength/Stiffness Parameters:

- Resilient Modulus (M_R)
- California Bearing Ratio (CBR)
- Permanent Deformation(PD)
- Angle of Friction and cohesion

Index Parameters:

- Gradation Characteristics
- Binder/Mortar Content
- Absorption
- Density
- Moisture Content

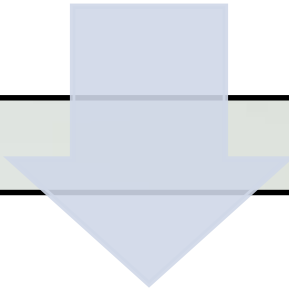
Drainage Parameters:

- Hydraulic Conductivity

OBJECTIVES

1st Goal – Collection of Material Input Data

- M_R , CBR, Shear strength, hydraulic conductivity of RAP & RCA
- Index properties
 - Gradation
 - Density
 - Moisture
 - Absorption



2nd Goal – Sensitivity Analyses on Pavement Performance

Overview of Research Plan

- **Task 1** – Initial Memorandum on Expected Research Benefits and Potential Implementation Steps
- **Task 2** – Data Collection
- **Task 3** – Sensitivity Analyses
- **Task 4** – Final Report

TASK 2 – DATA COLLECTION

List of data that has been collected:

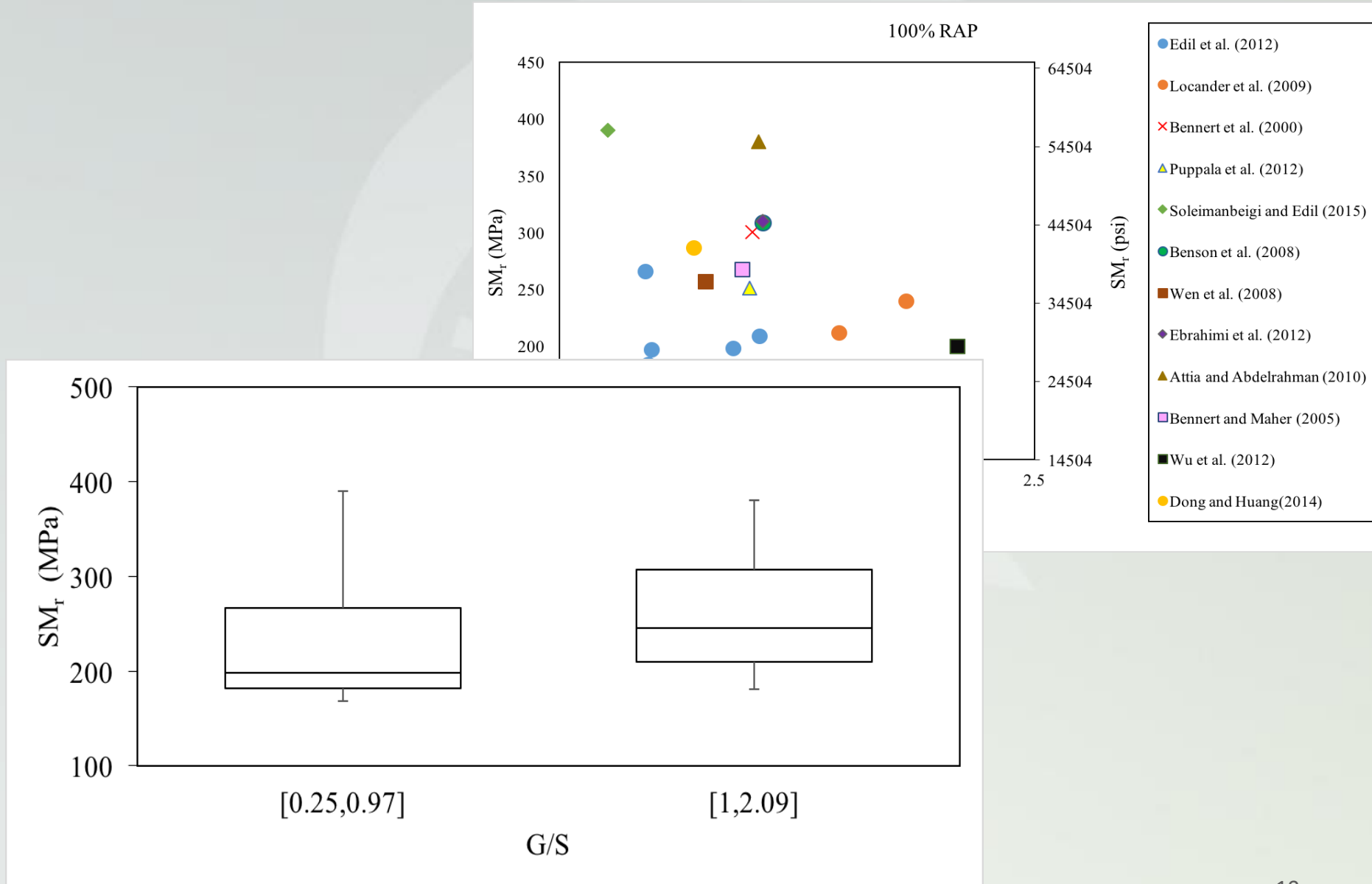
- Index Properties
 - Gradation characteristics
 - Atterberg limits
 - Moisture
 - Density
 - Binder/mortar content
- Strength/Stiffness Properties
 - CBR
 - Angle of friction, cohesion
 - M_R
- Hydraulic Conductivity



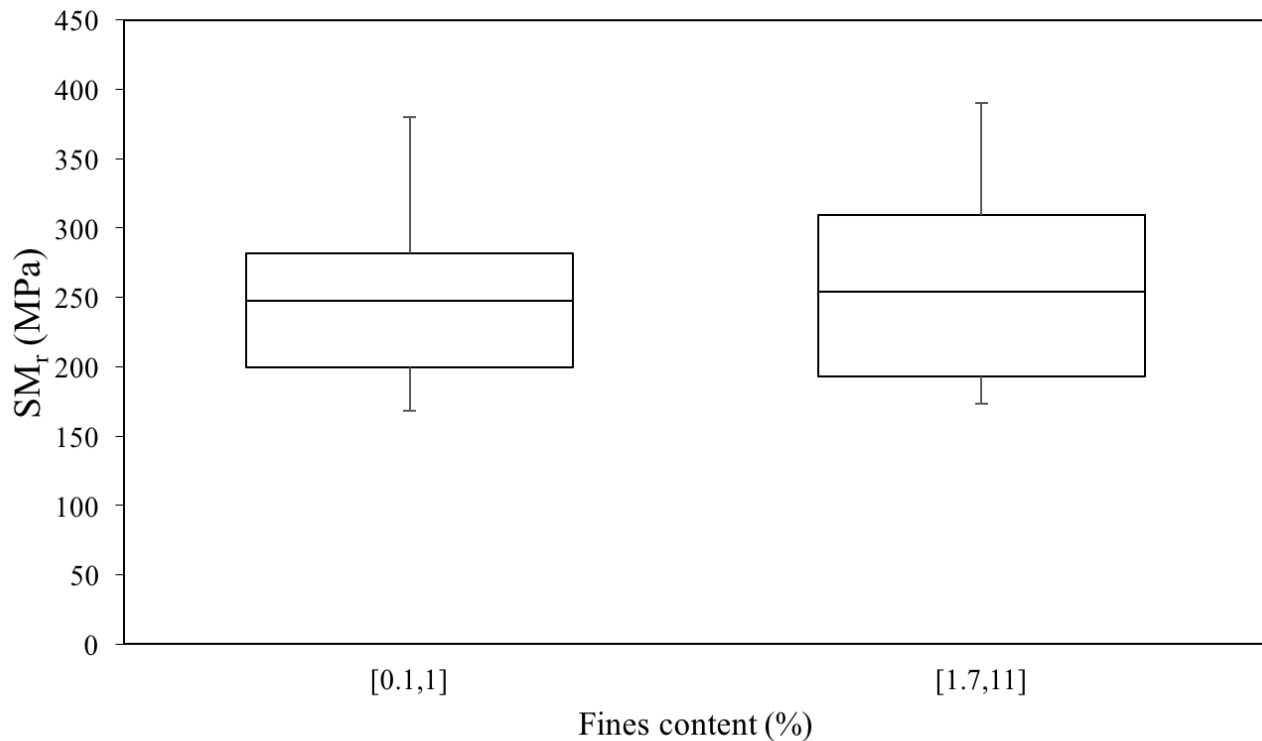
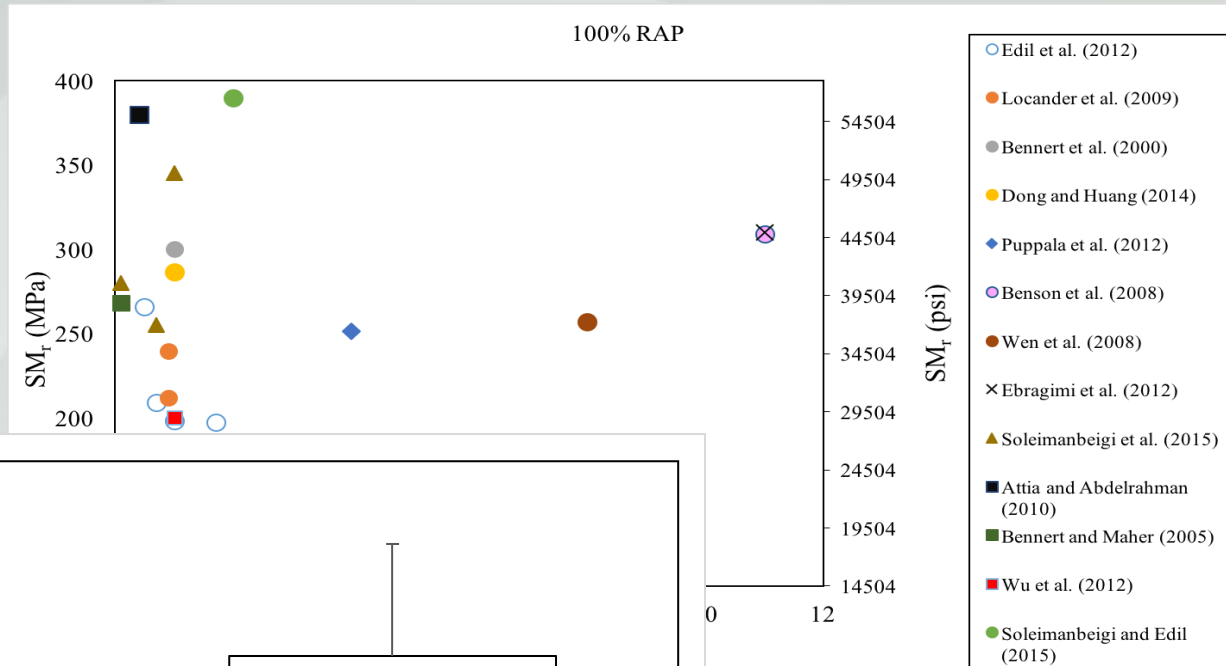
SUMMARY OF RAP & RCA CHARACTERISTICS

Characteristics	RAP			RCA		
	Lower Limit	Median	Upper Limit	Lower Limit	Median	Upper Limit
% Gravel	3	45	68.1	31.8	51	94.1
% Sand	28.1	54	97	4.9	46.3	64.9
% Fines	0	1	11	0.1	2.8	12.8
D ₁₀ (mm/inch)	10 ⁻¹ / 3.9x10 ⁻³	5x10 ⁻¹ / 1.96x10 ⁻²	1/ 3.93x10 ⁻²	10 ⁻¹ / 3.9x10 ⁻³	2.3x10 ⁻¹ / 9x10 ⁻³	4.3x10 ⁻¹ / 1.7x10 ⁻²
D ₃₀ (mm/inch)	8x10 ⁻² / 3.1x10 ⁻³	1.5/ 6x10 ⁻²	4.9/ 1.9x10 ⁻¹	2x10 ⁻¹ / 7.9x10 ⁻³	1.2/ 4.72x10 ⁻²	6.5/ 2.56x10 ⁻¹
D ₆₀ (mm/inch)	1.5x10 ⁻¹ / 5.9x10 ⁻³	4.82/ 1.89x10 ⁻¹	10.4/ 4.09x10 ⁻¹	6x10 ⁻¹ / 2.36x10 ⁻²	6.8/ 2.67x10 ⁻¹	16.3/ 6.42x10 ⁻¹
C _u	5	10.65	40	2.1	32	66
C _c	0.21	1.2	8	0.14	1.4	6
G _s	2.19	2.395	2.87	2.12	2.39	2.7
MDU (kN/m ³)/(pcf)	17.2 (110)	19.6 (126)	24.1 (155)	18.3 (118)	19.7 (127)	21.7 (140)
OMC(%)	4	6.05	10.7	6.1	10.8	14.8
SM _r (MPa/psi)	168/ 24366.3	261.5/ 37927.36	400/ 58015.1	123.4/ 17897.65	183/ 26541.9	370/ 53664
CBR (%)	18	28	68	58	146	169
Hydraulic conductivity (m/s/ft/hr)	1.8x10 ⁻⁷ / 2.12x10 ⁻³	6.89x10 ⁻⁵ / 8.14x10 ⁻¹	1.14x10 ⁻³ / 1.35x10	1.05x10 ⁻⁶ / 1.24x10 ⁻²	1.7x10 ⁻⁵ / 2.01x10 ⁻¹	1.2x10 ⁻³ / 1.42 x10

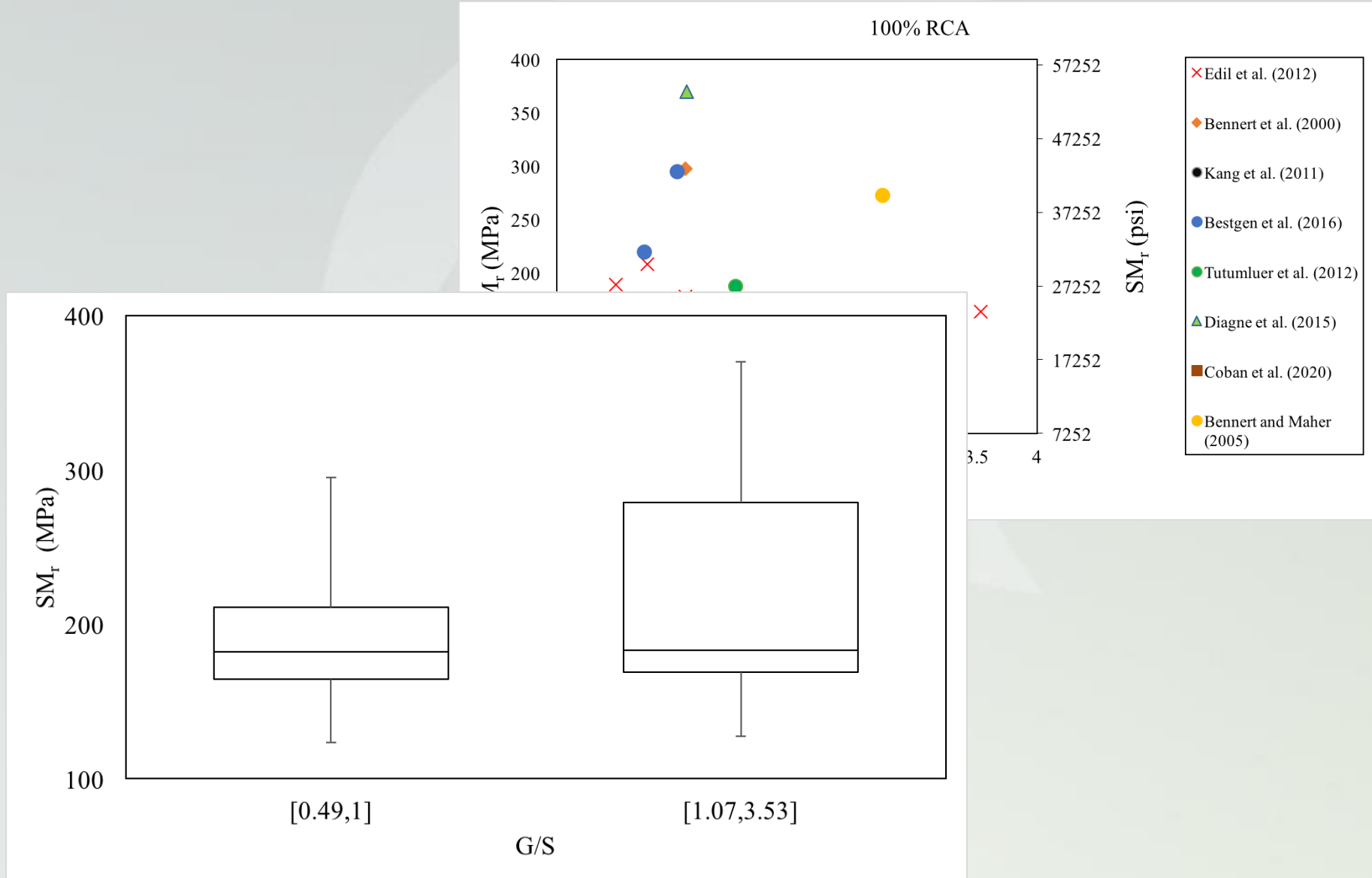
G/S ratio vs. SM_r – RAP



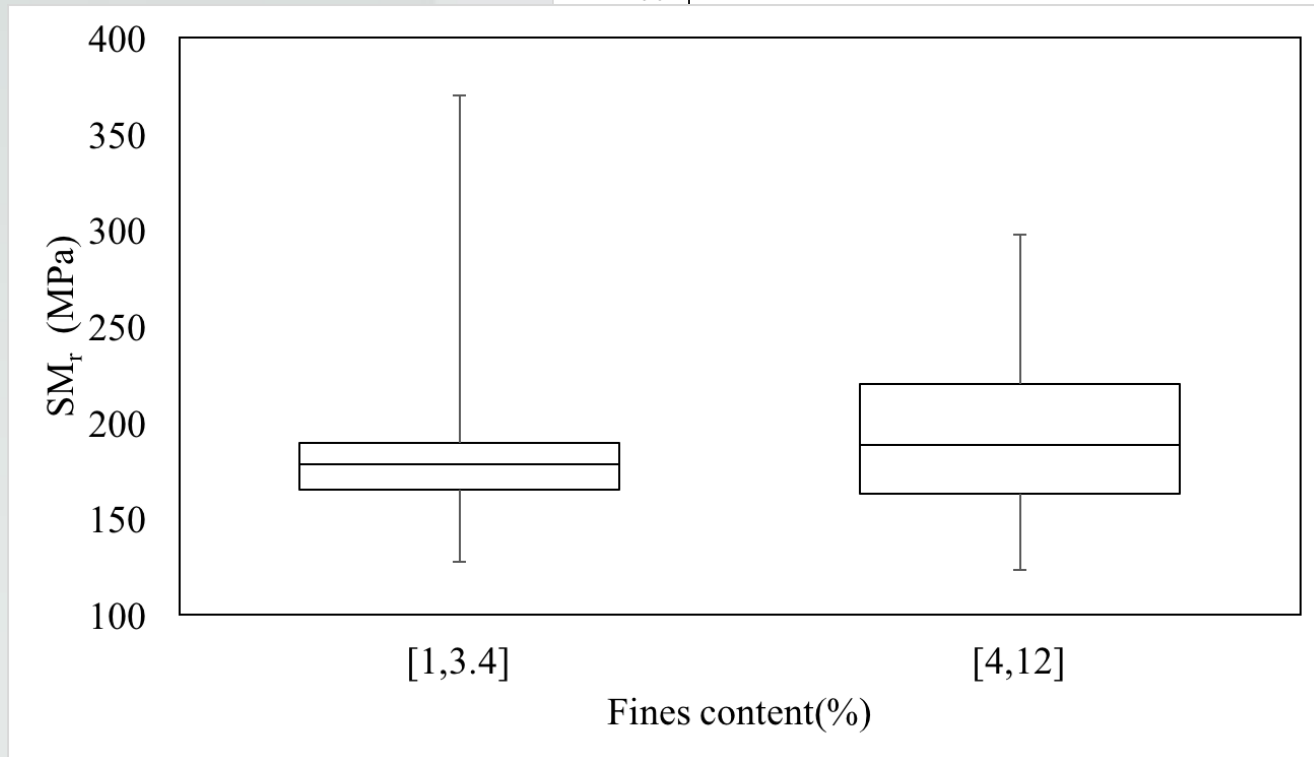
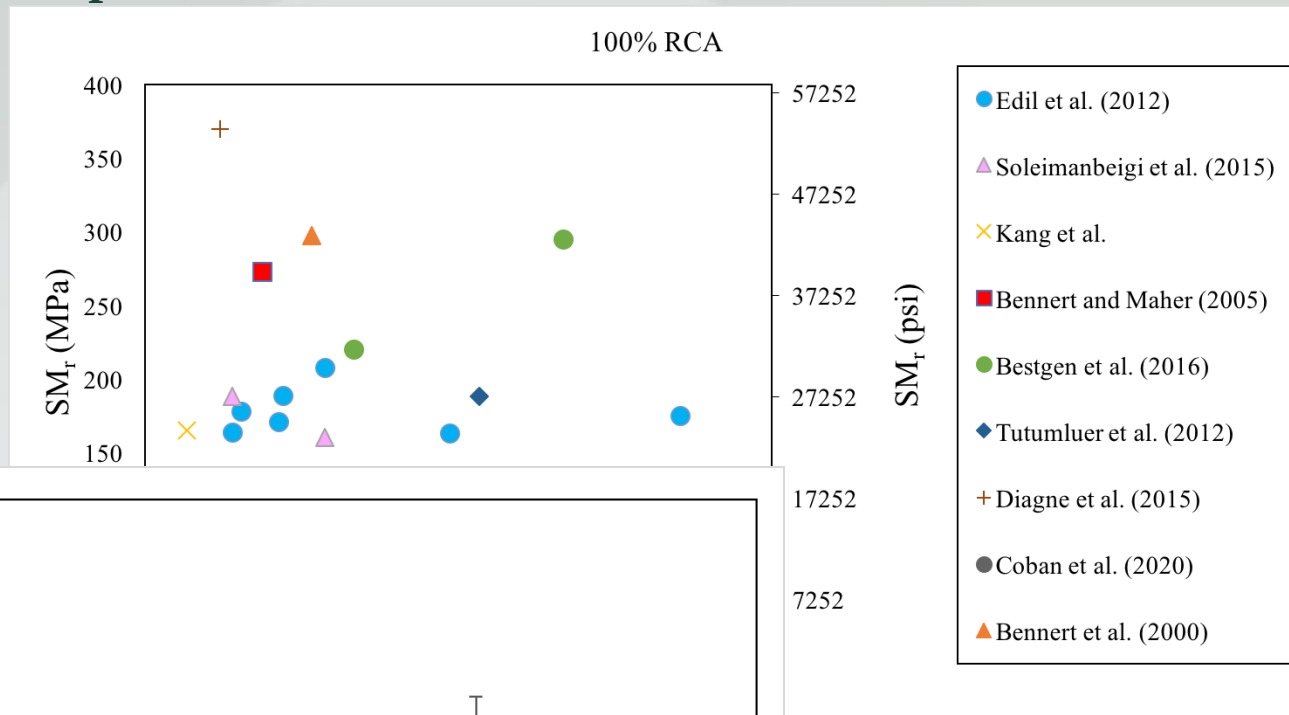
Fines content vs. SM_r – RAP



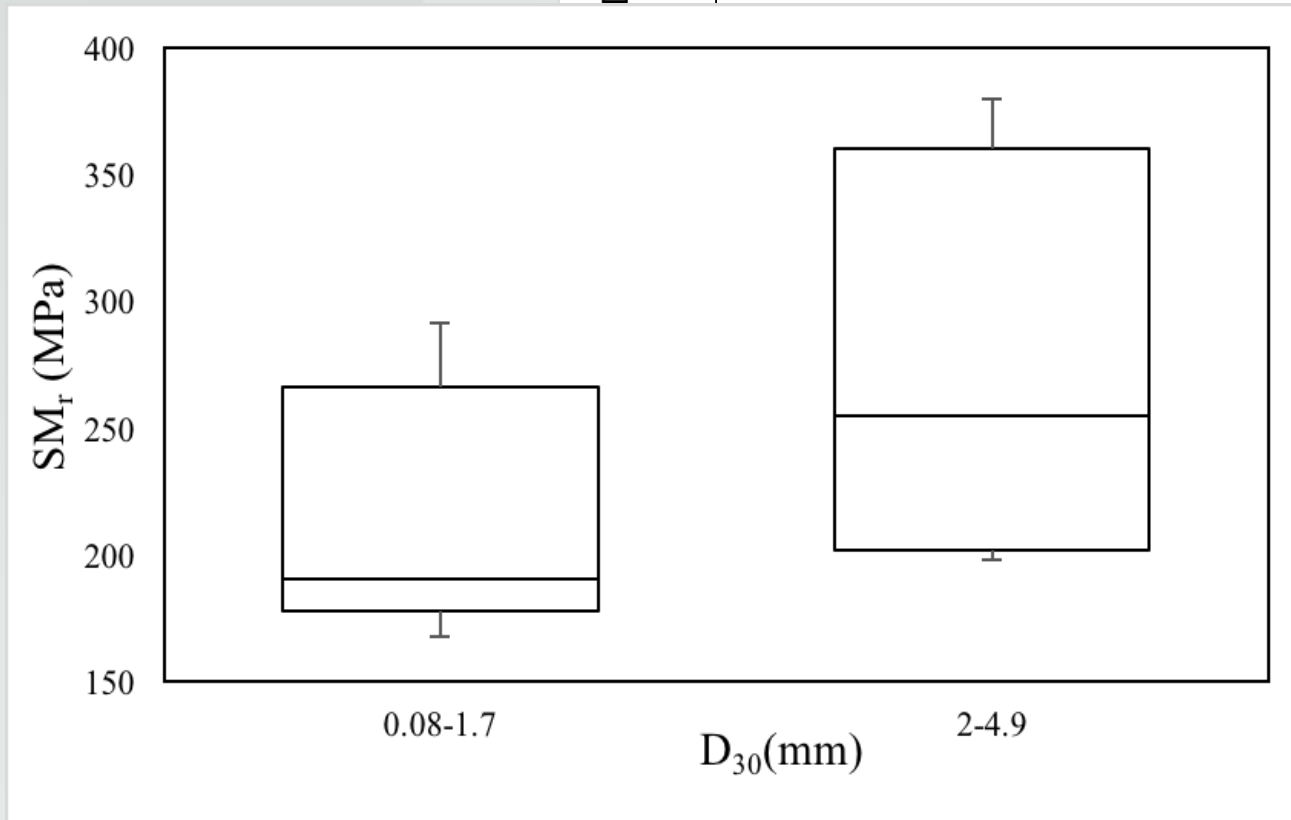
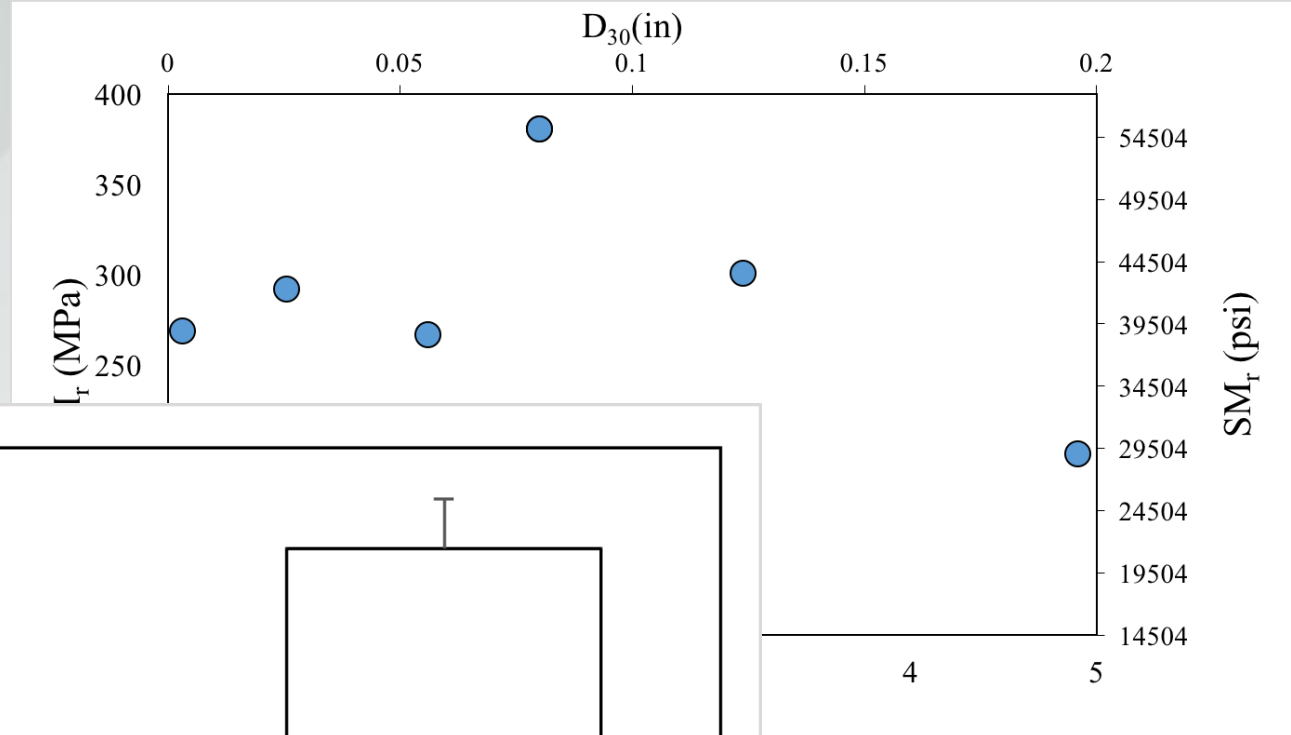
G/S ratio vs. SM_r – RCA



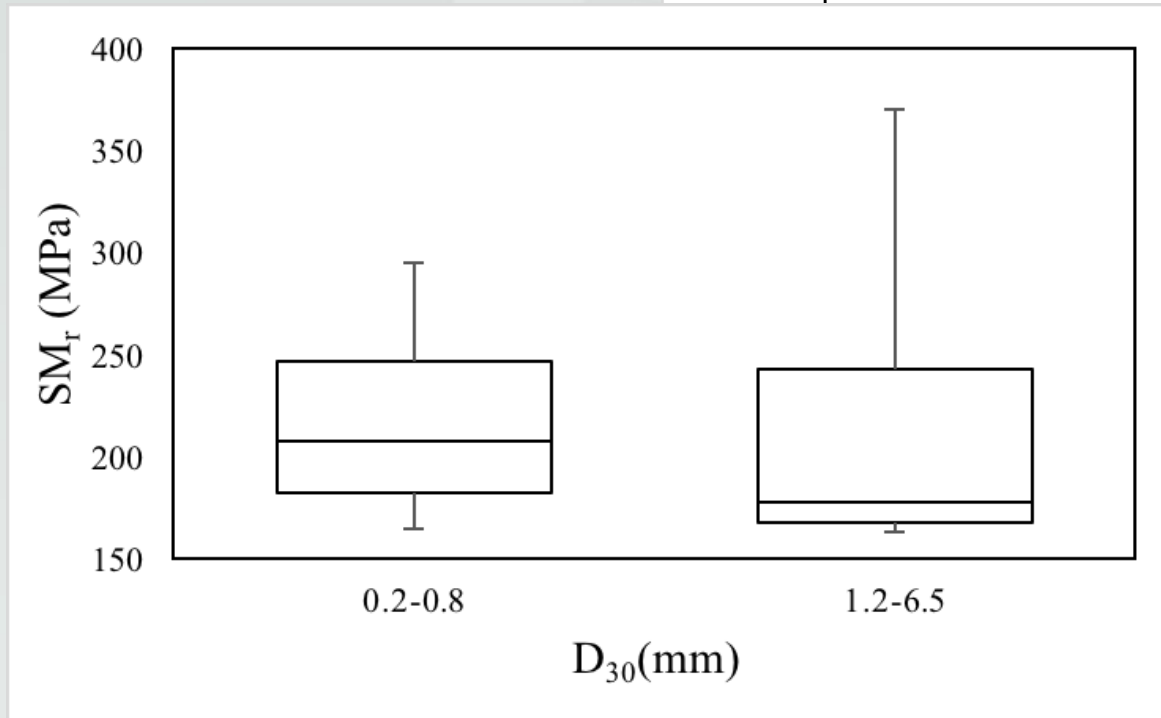
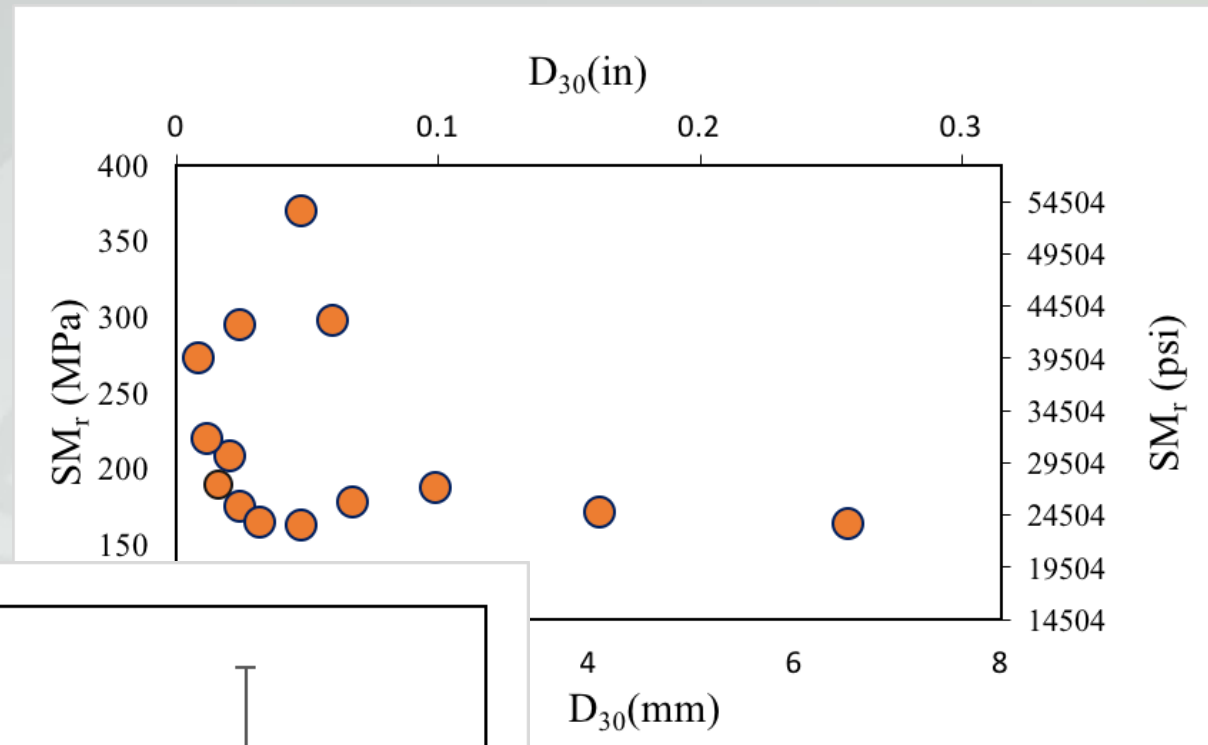
Fines content vs. SM_r – RCA



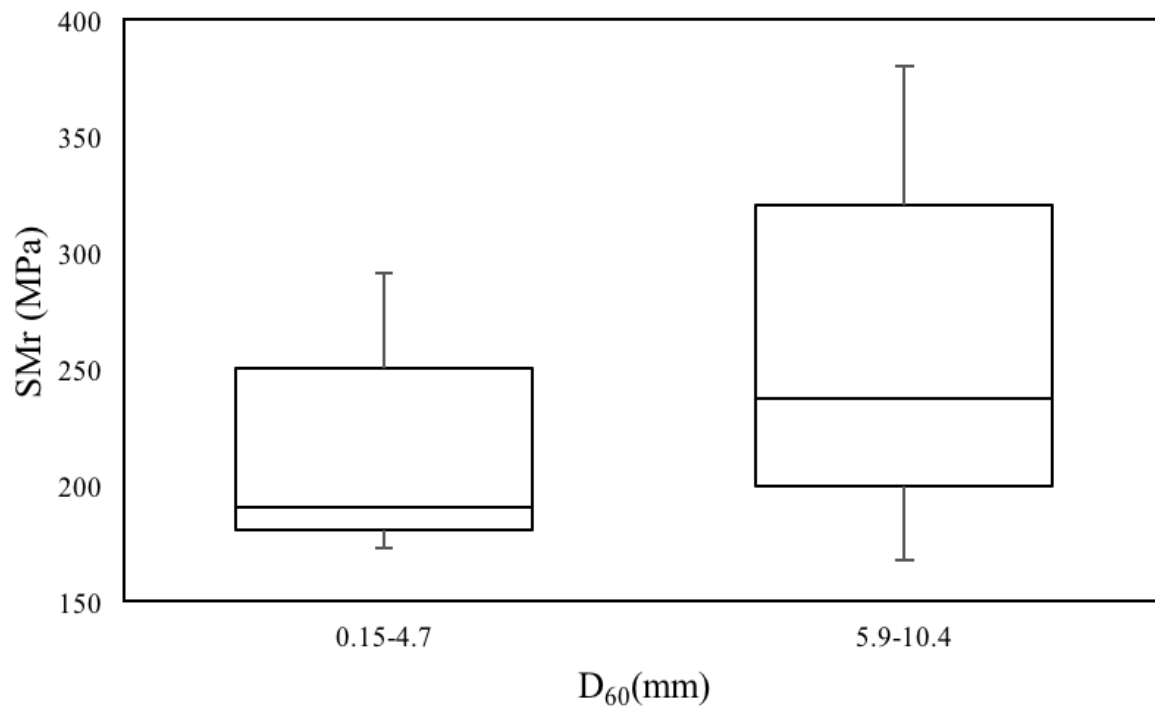
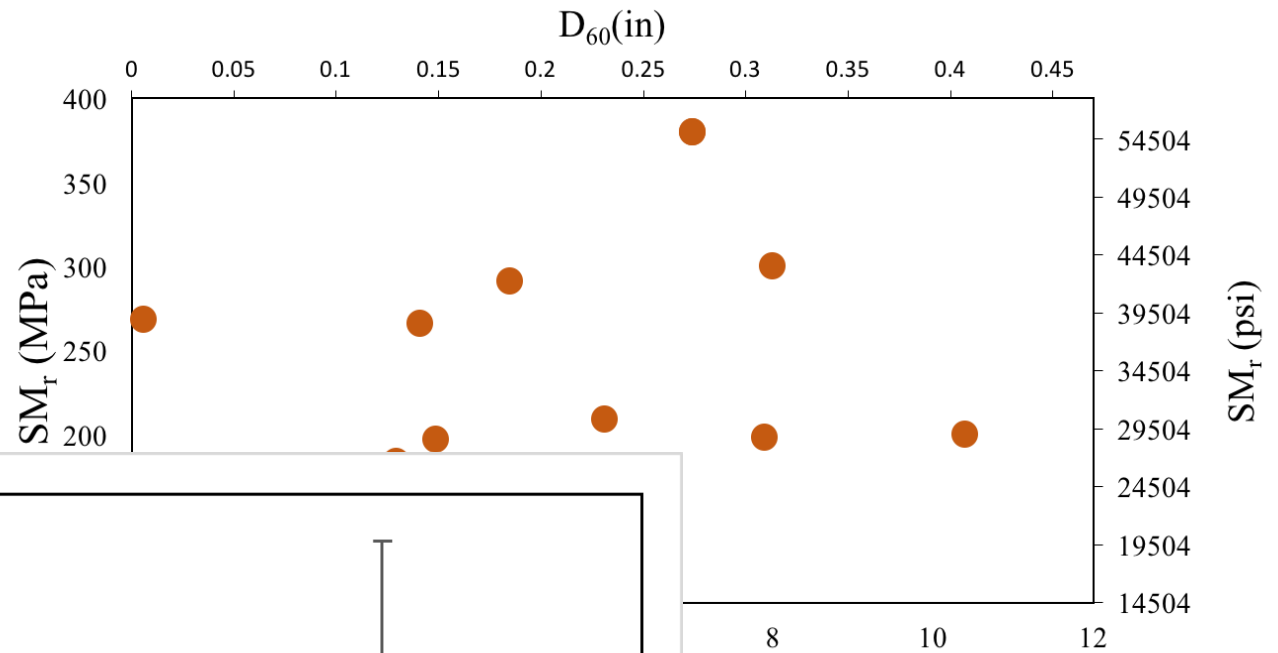
D₃₀ vs. SM_r – RAP



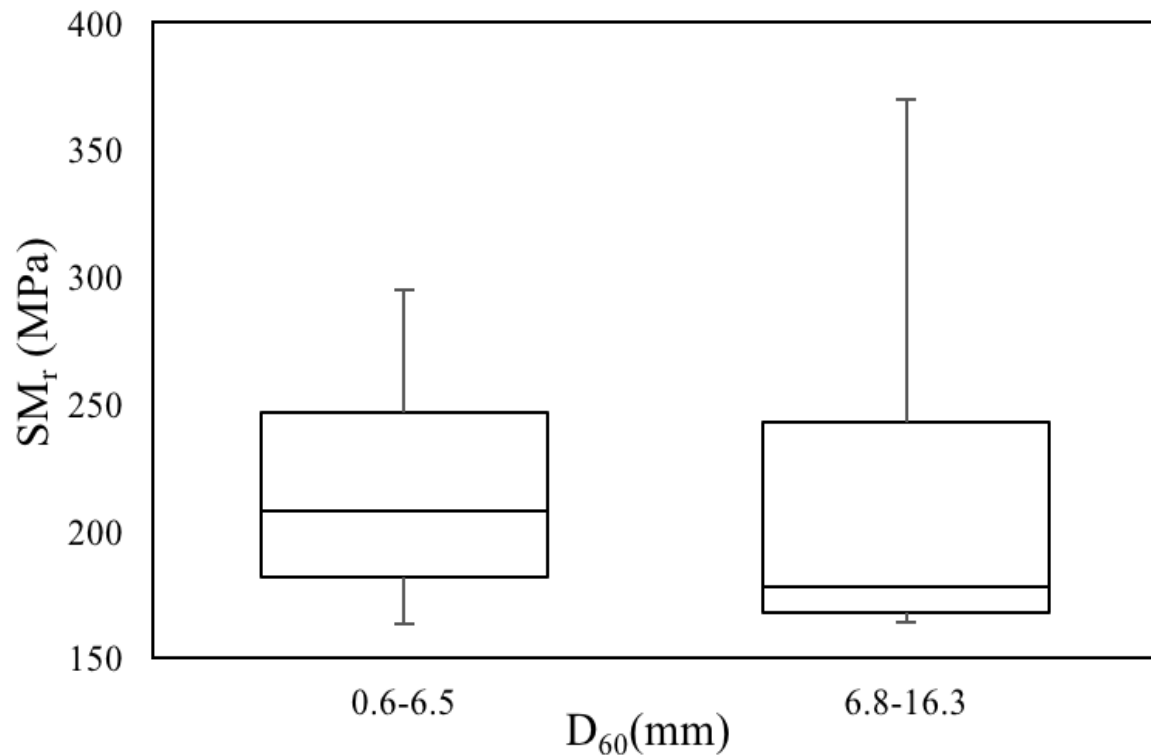
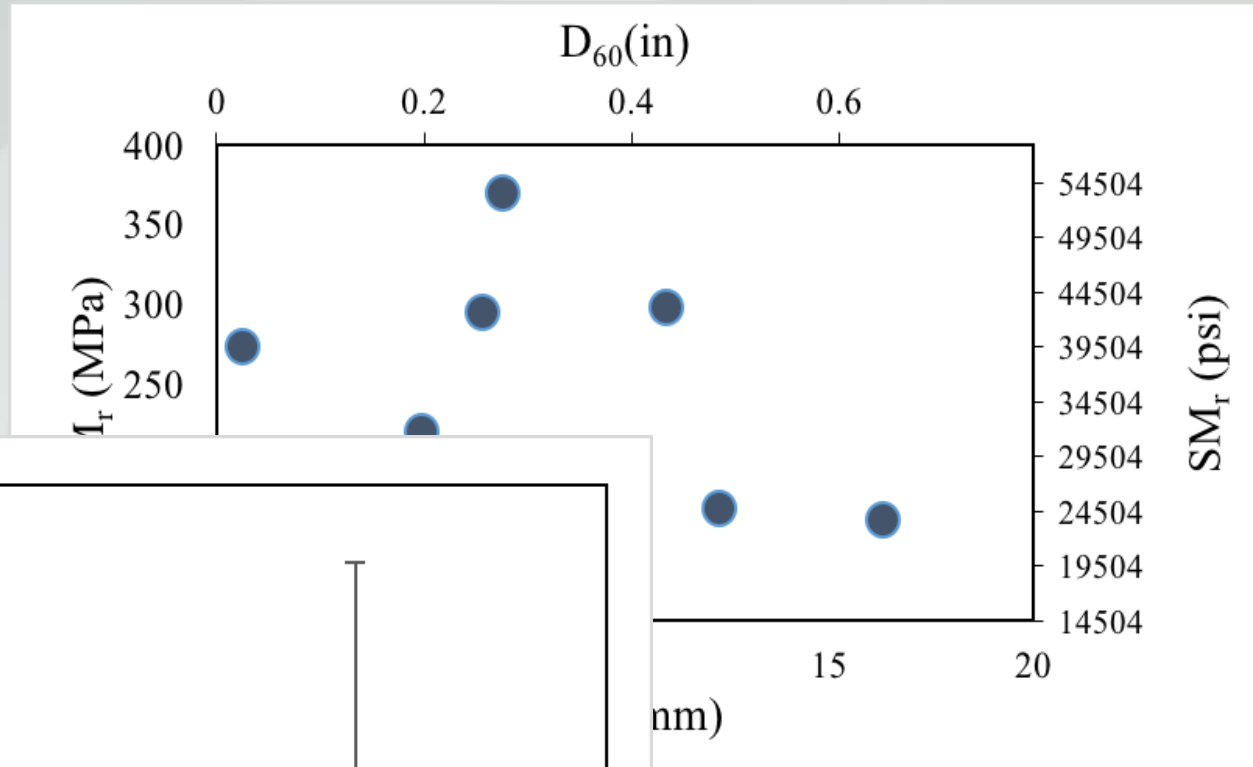
D₃₀ vs. SM_r – RCA



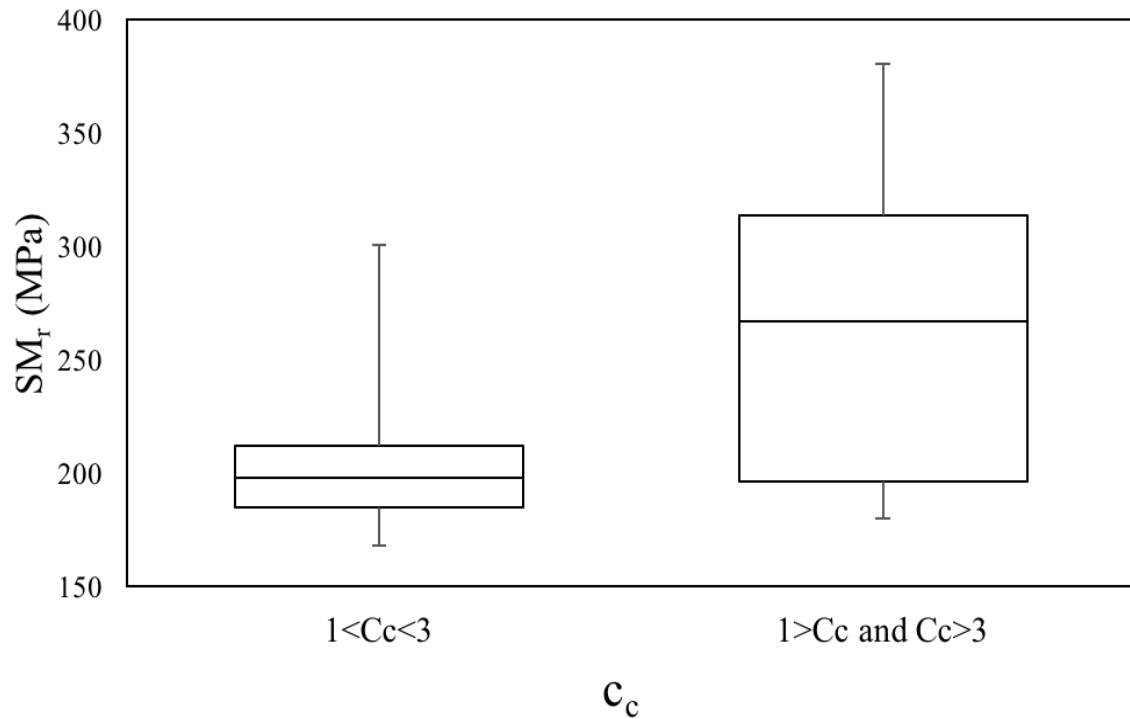
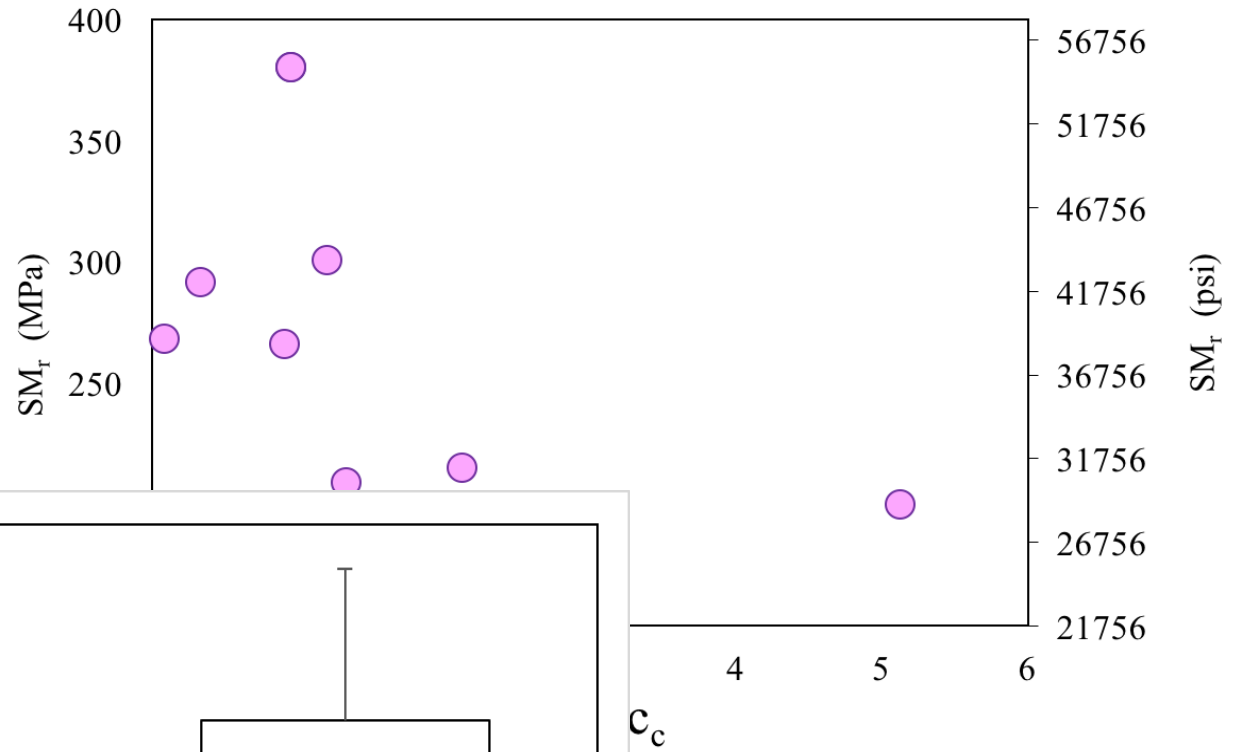
D₆₀ vs. SM_r – RAP



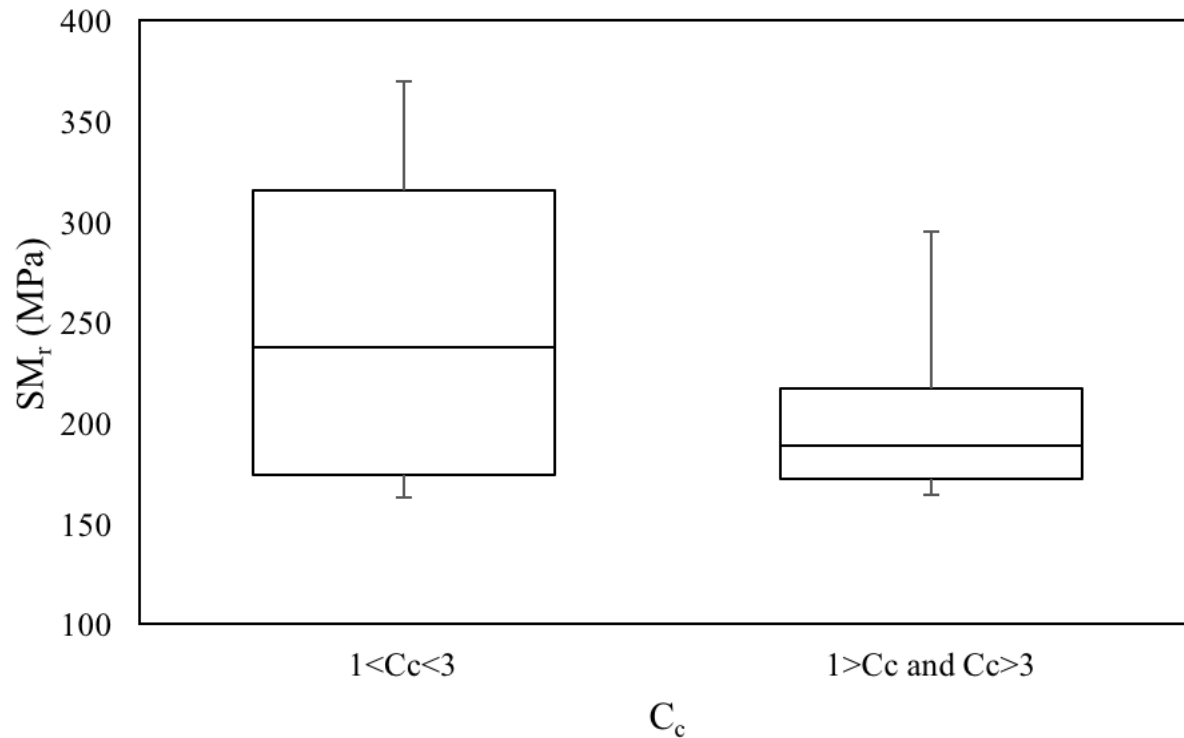
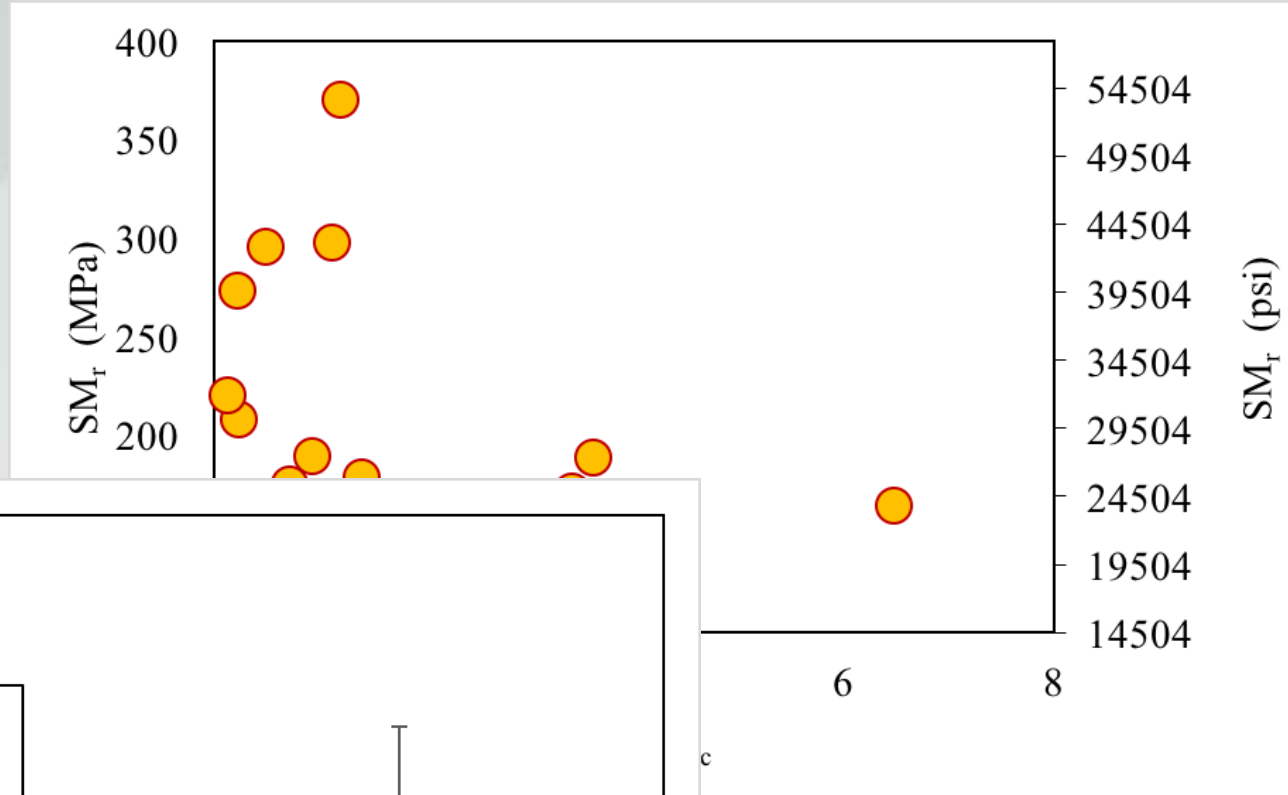
D₆₀ vs. SM_r – RCA



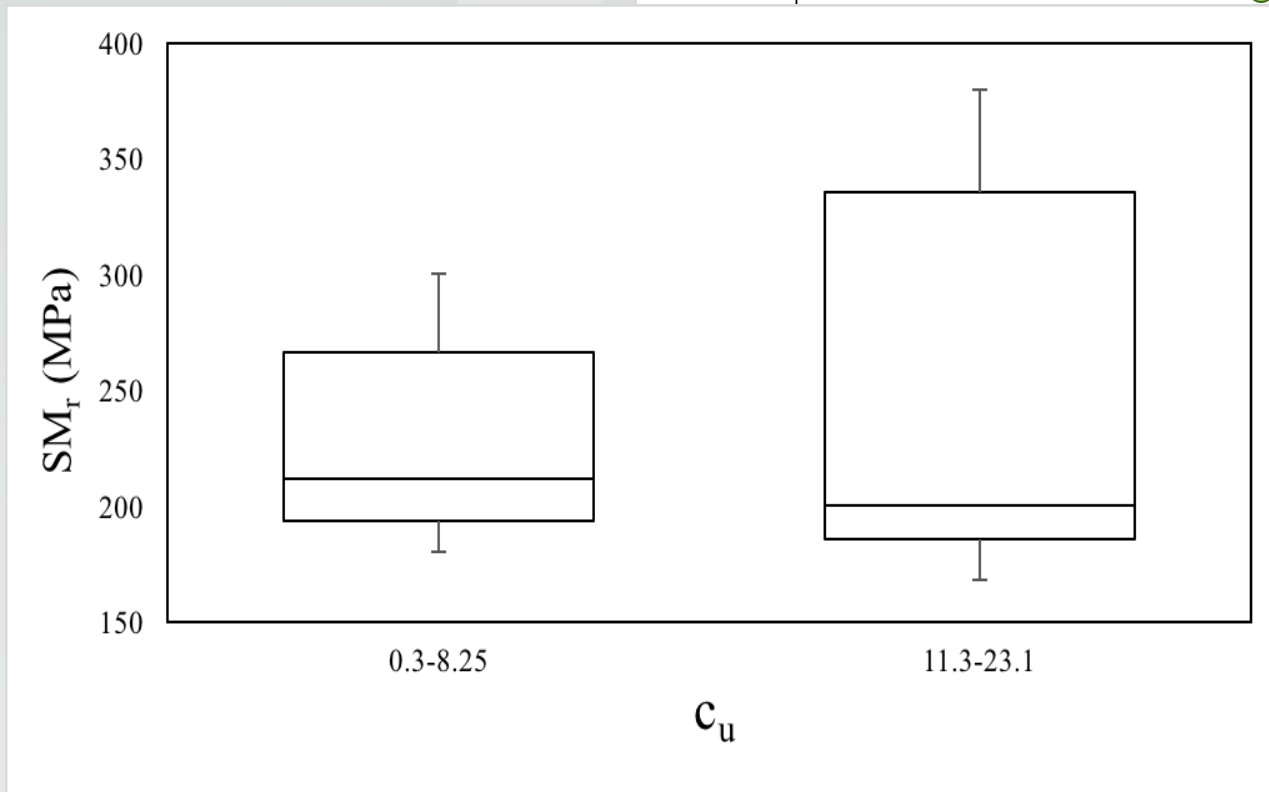
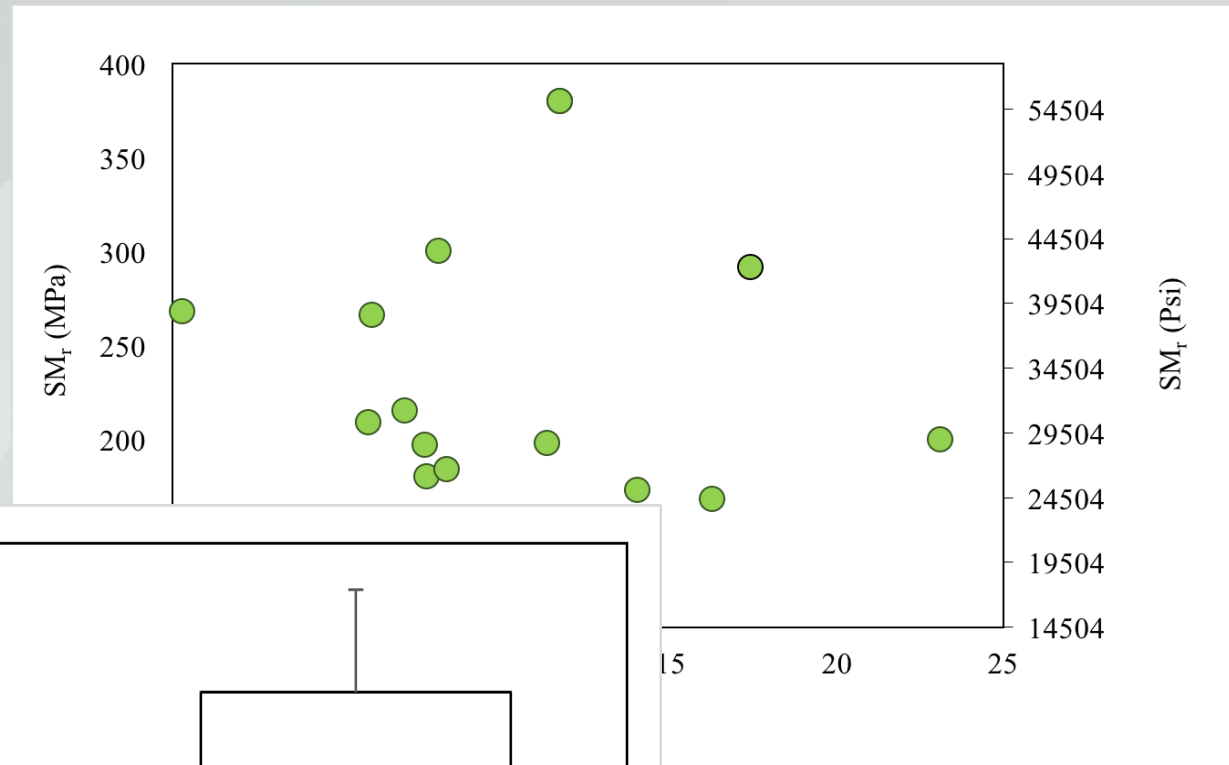
C_c vs. SM_r – RAP



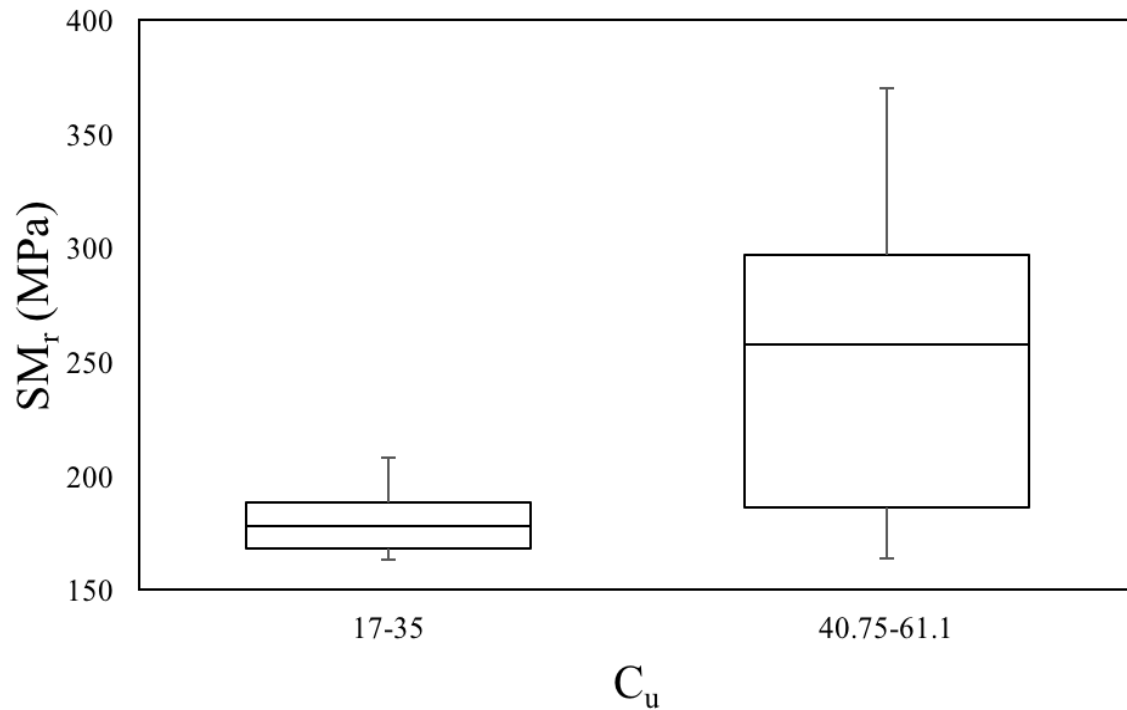
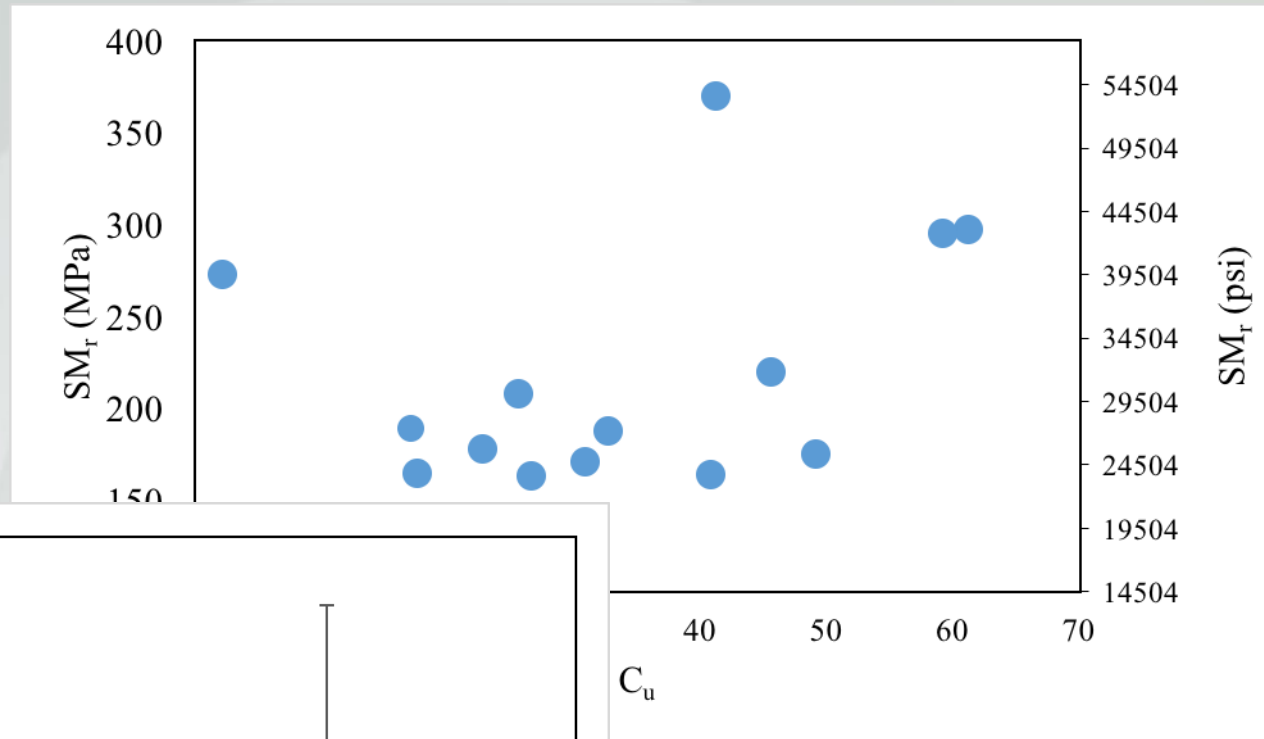
C_c vs. SM_r – RCA



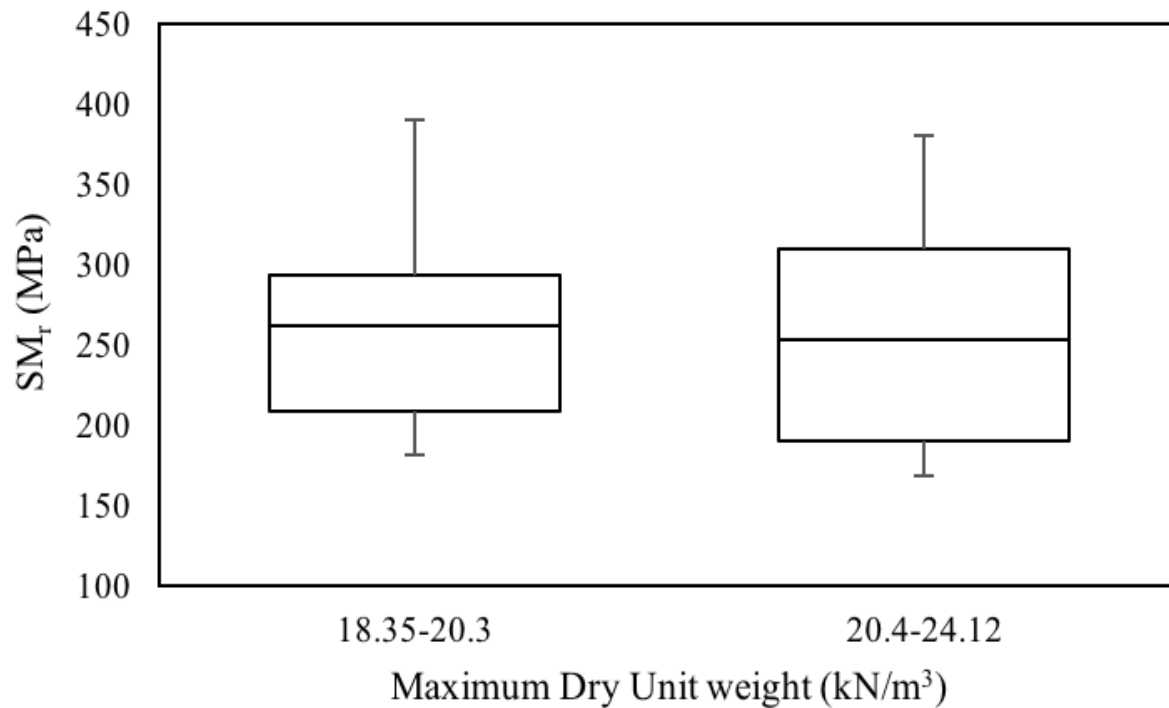
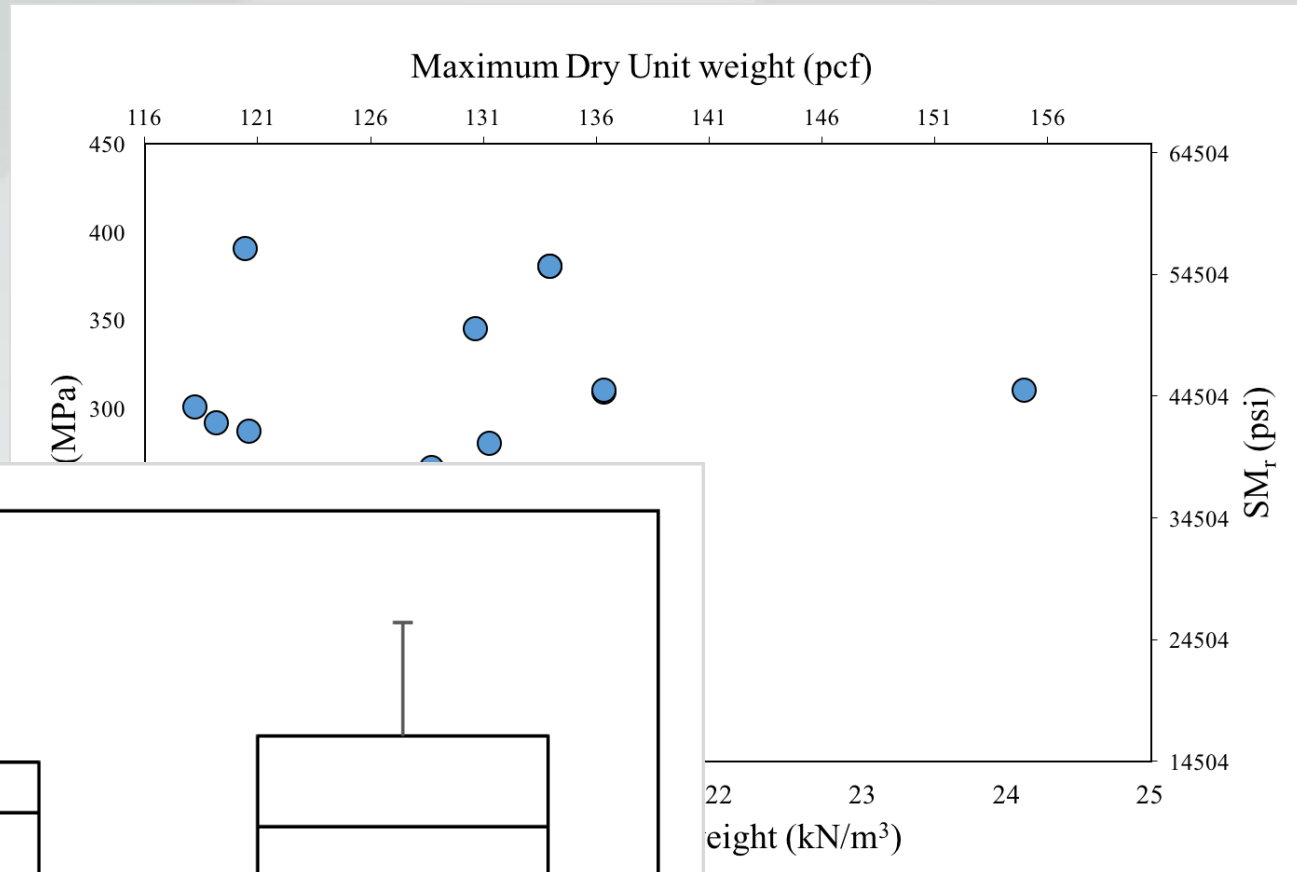
C_u vs. SM_r – RAP



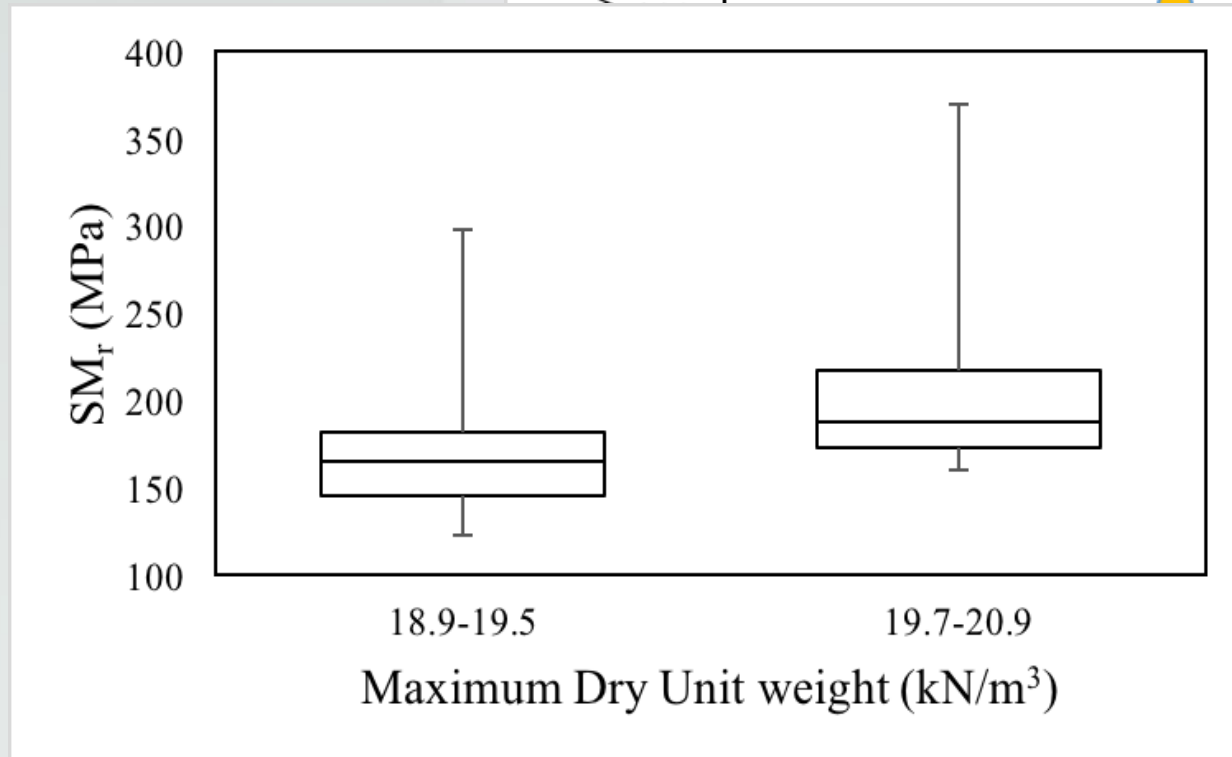
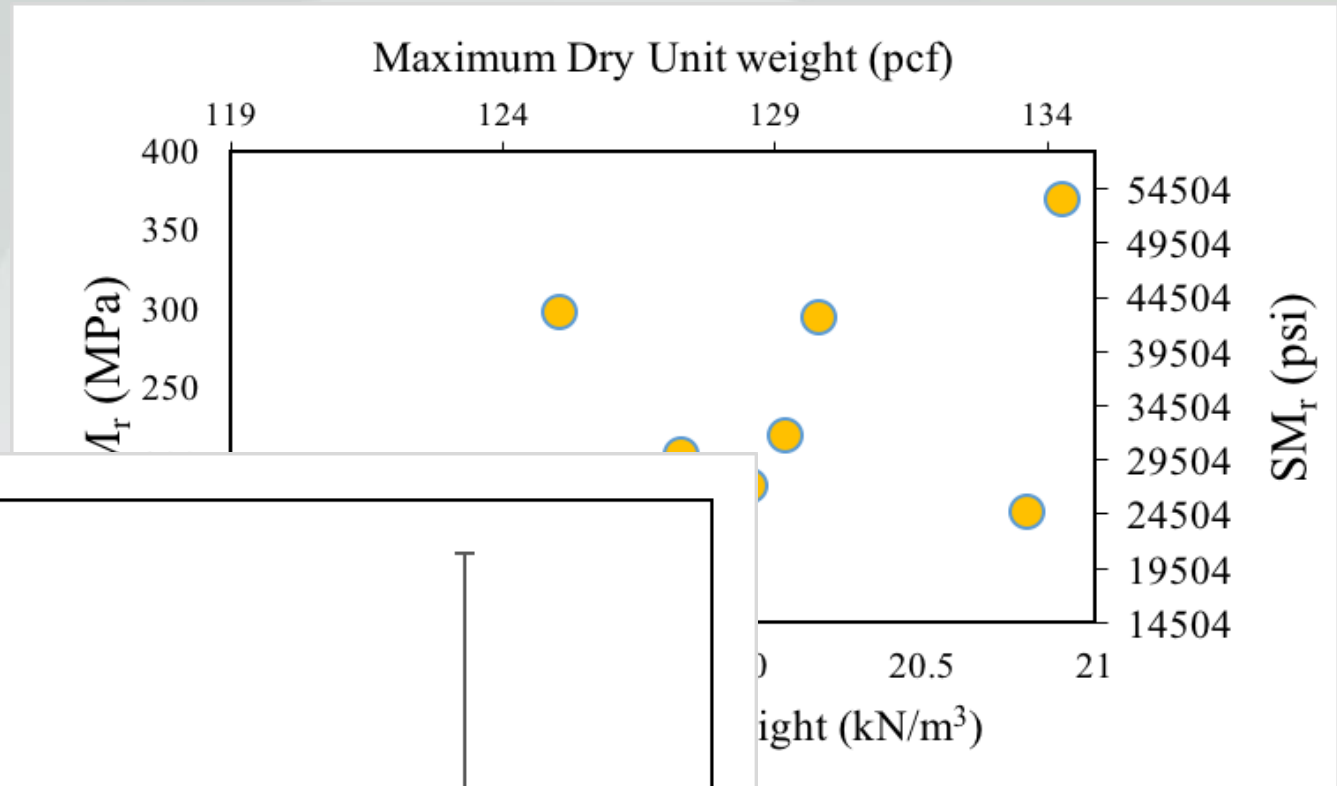
C_u vs. SM_r – RCA



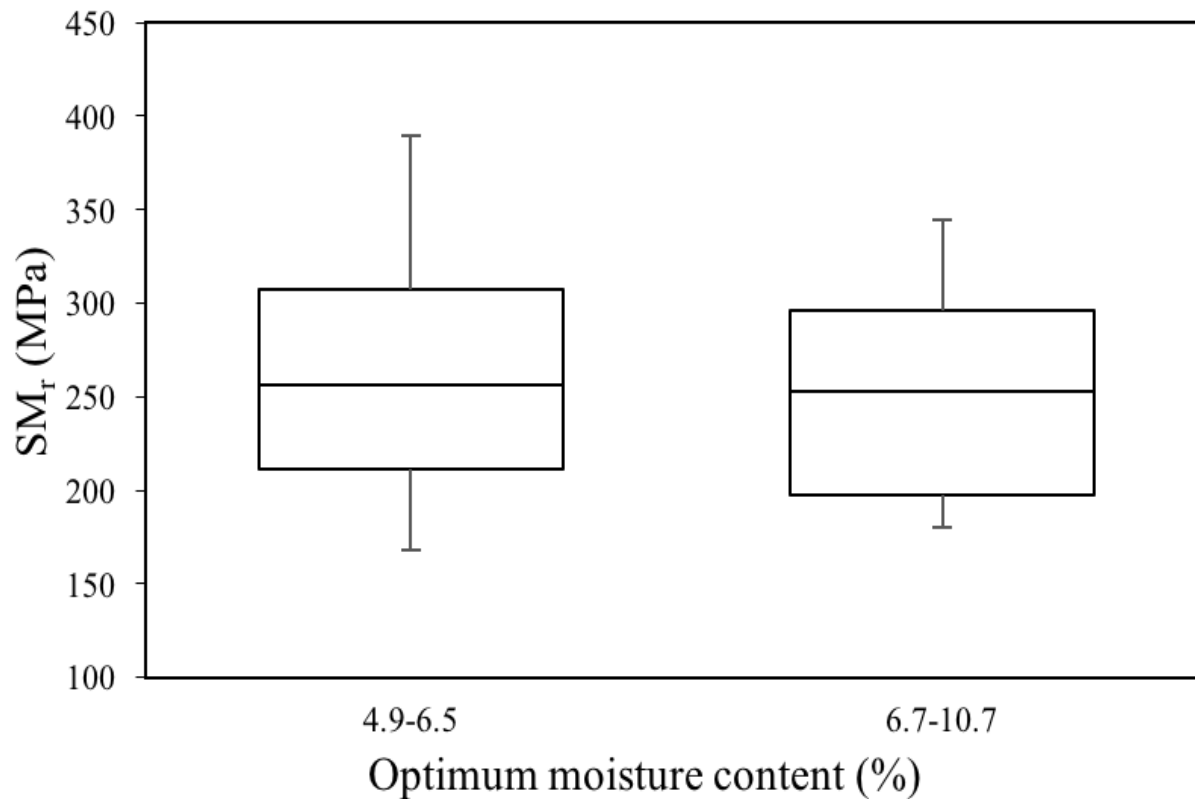
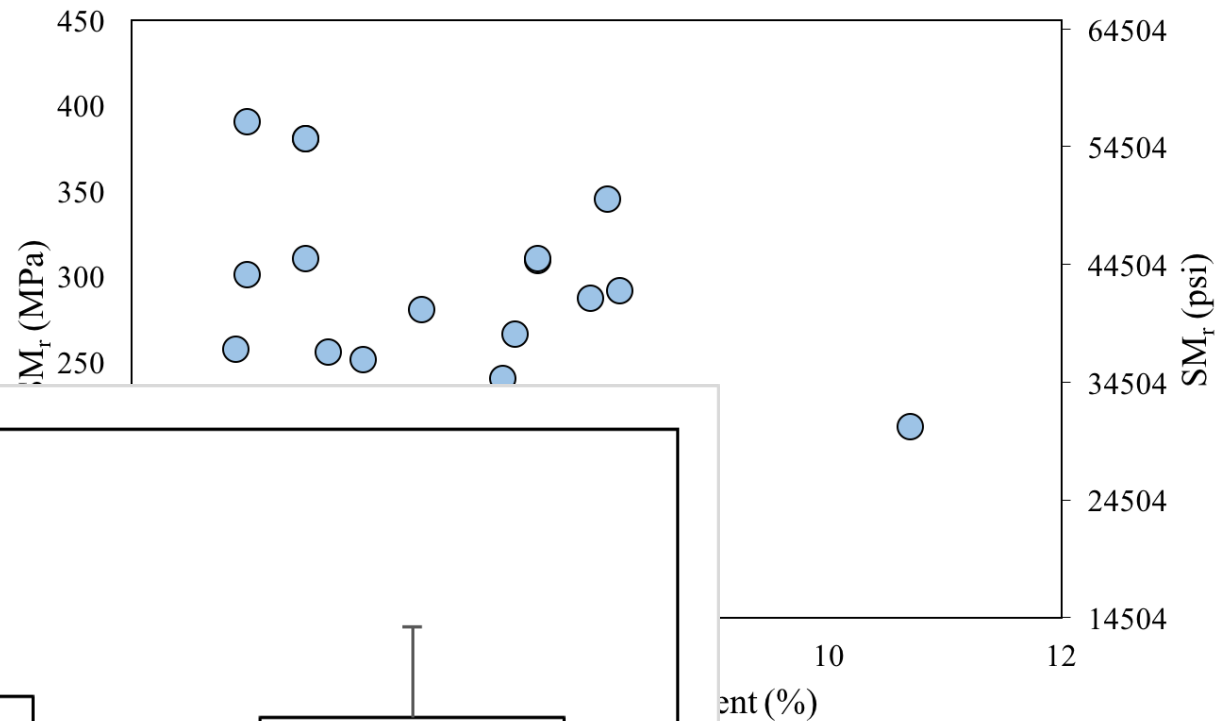
MDU vs. SM_r – RAP



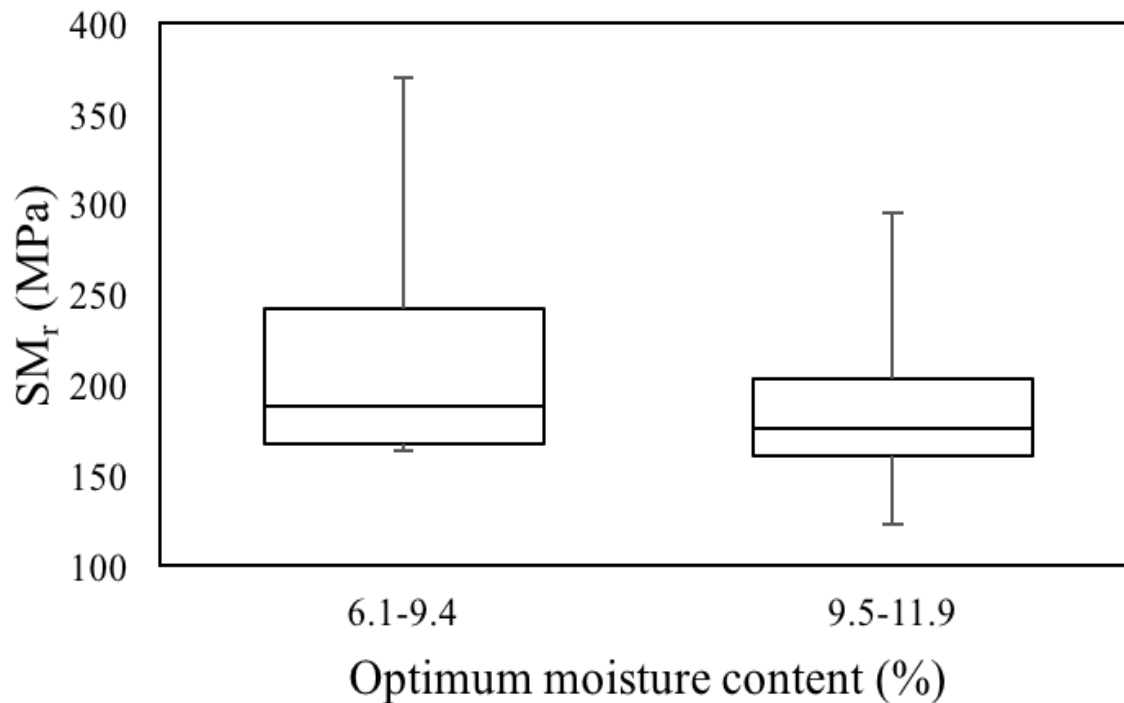
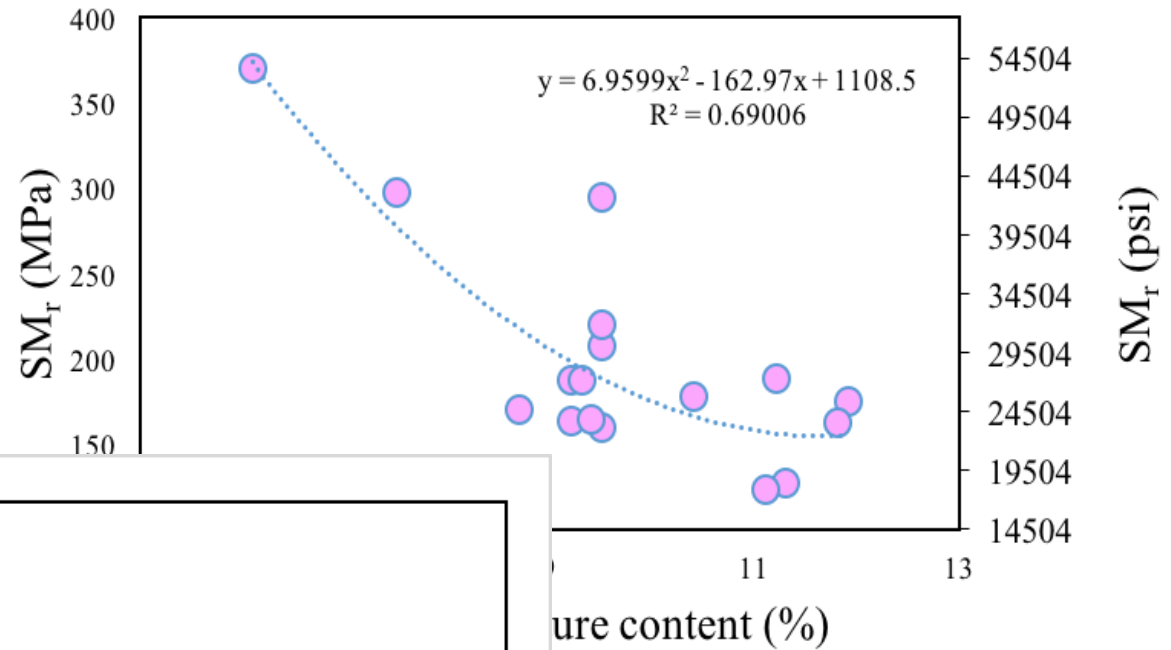
MDU vs. SM_r – RCA



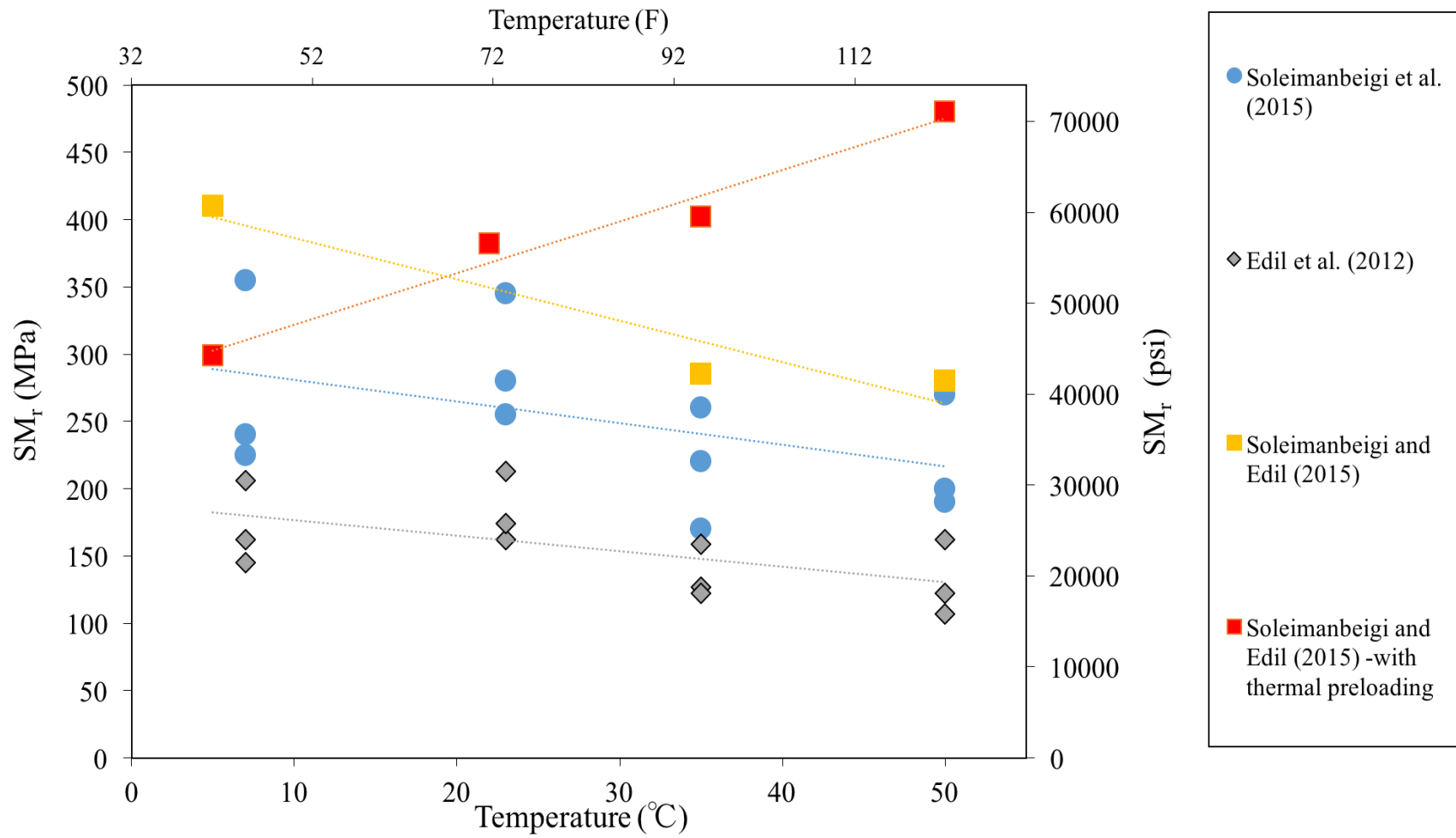
OMC vs. SM_r – RAP



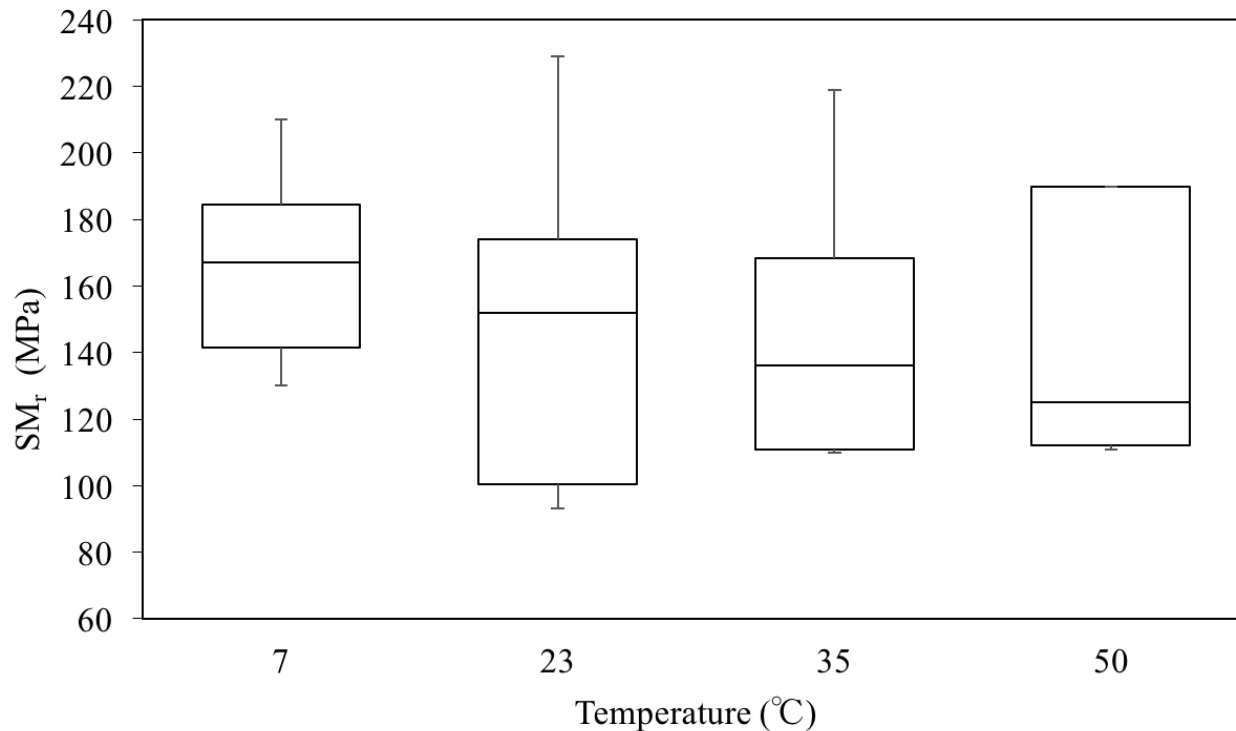
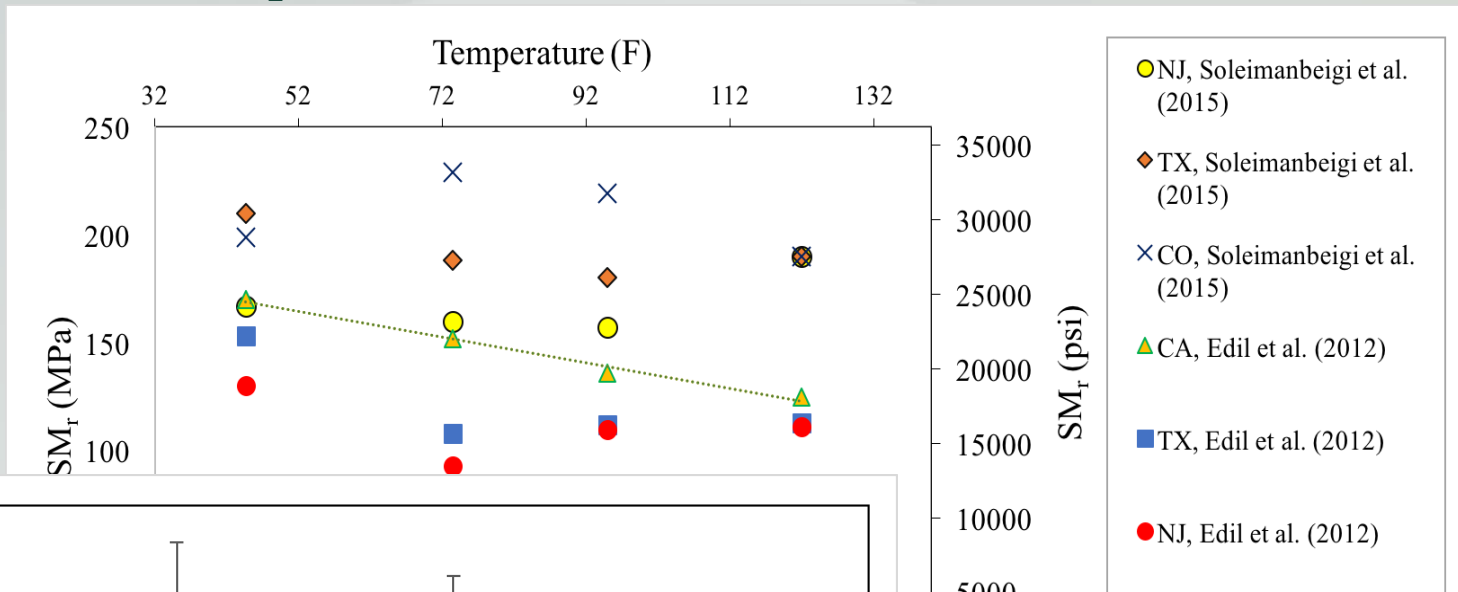
OMC vs. SM_r – RCA



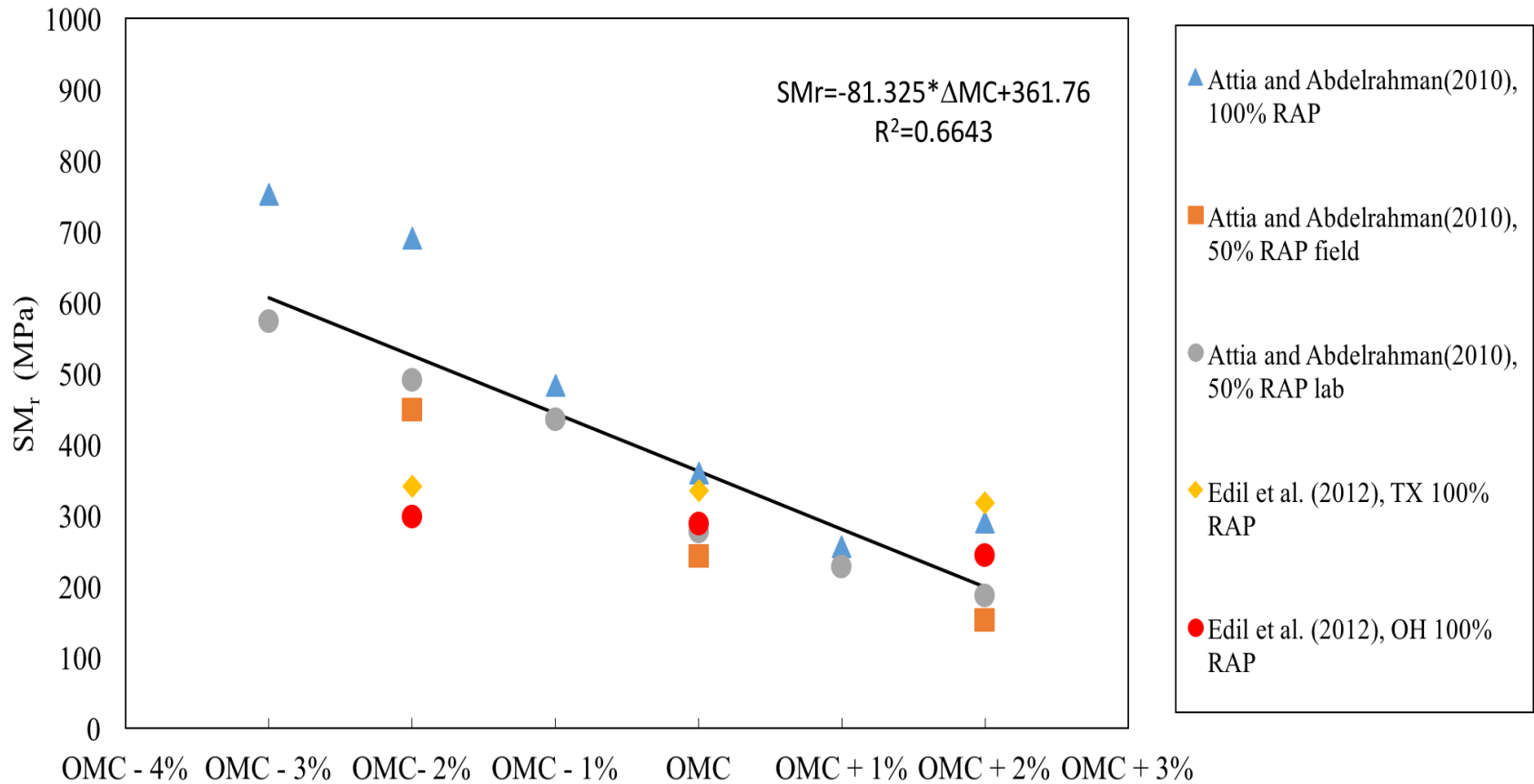
Temperature vs. SM_r – RAP



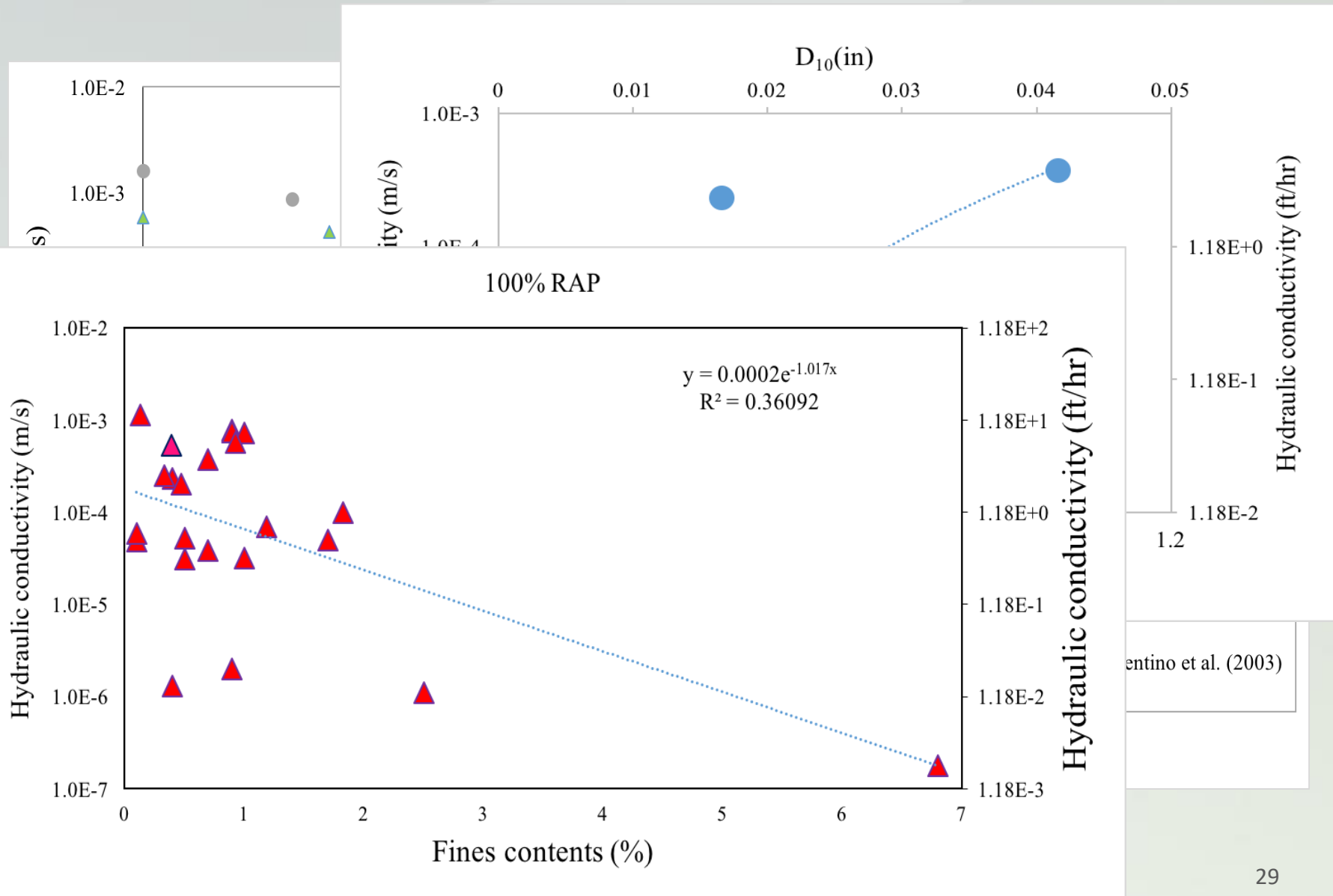
Temperature vs. SM_r – RCA



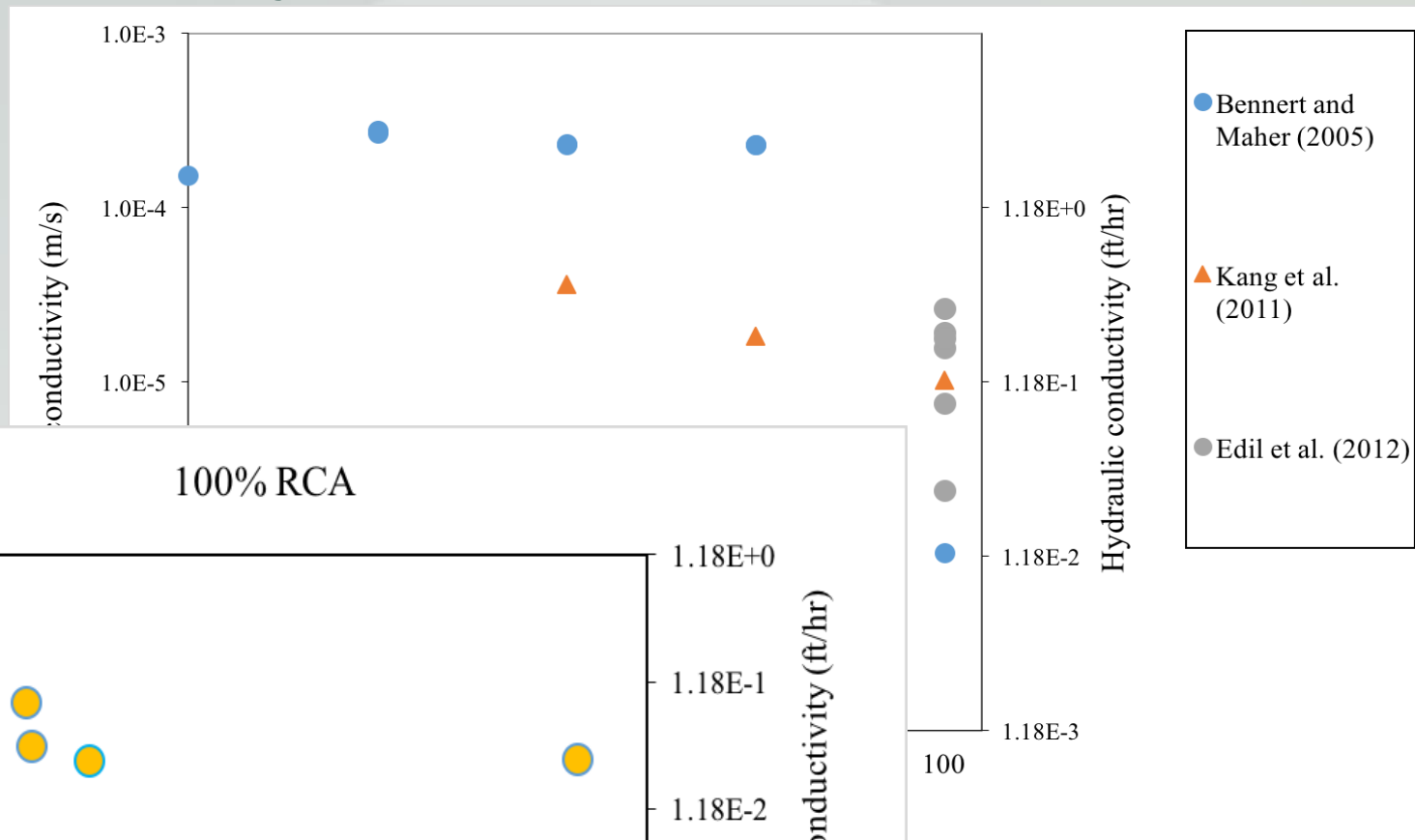
OMC vs. SM_r – RAP



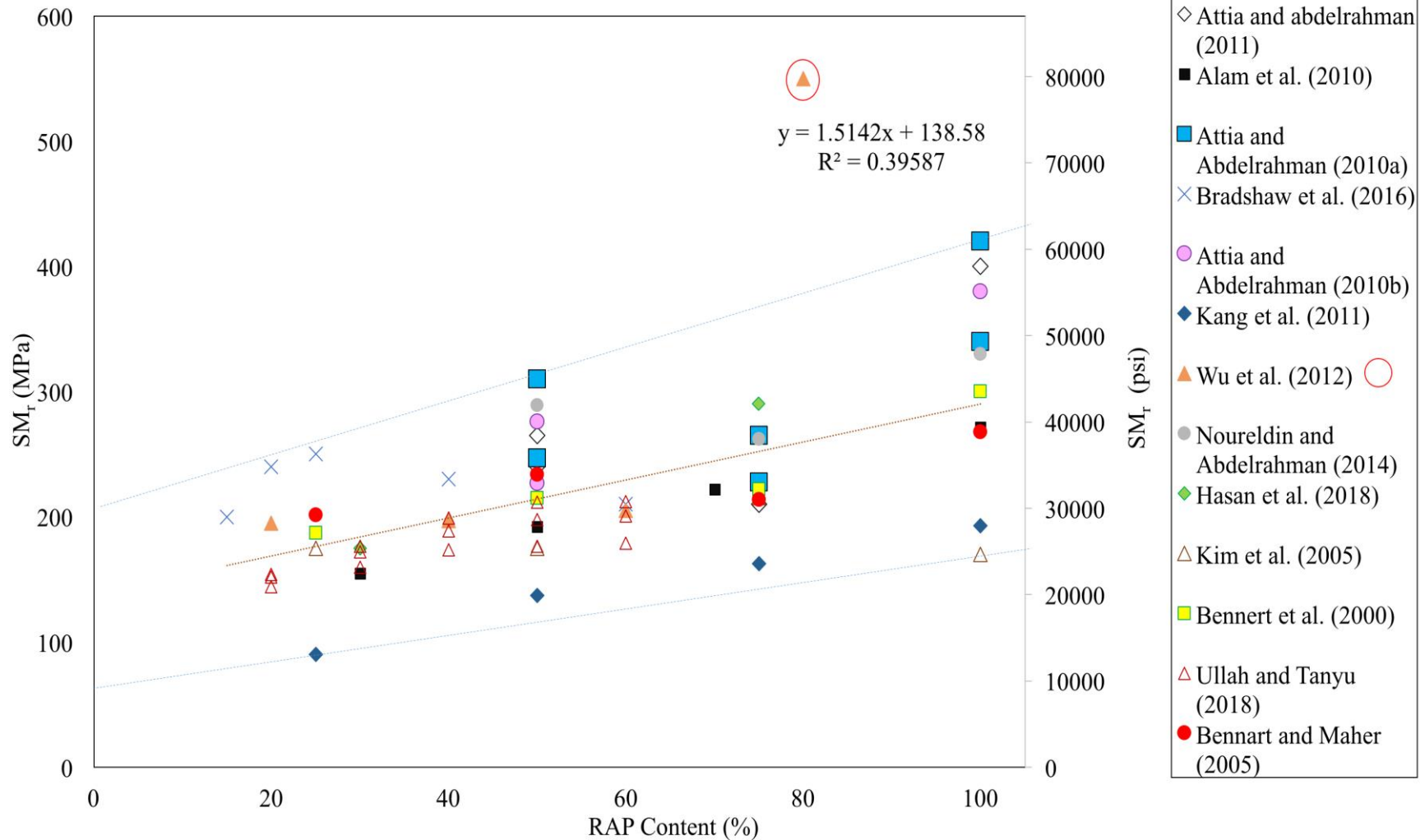
Hydraulic conductivity – RAP



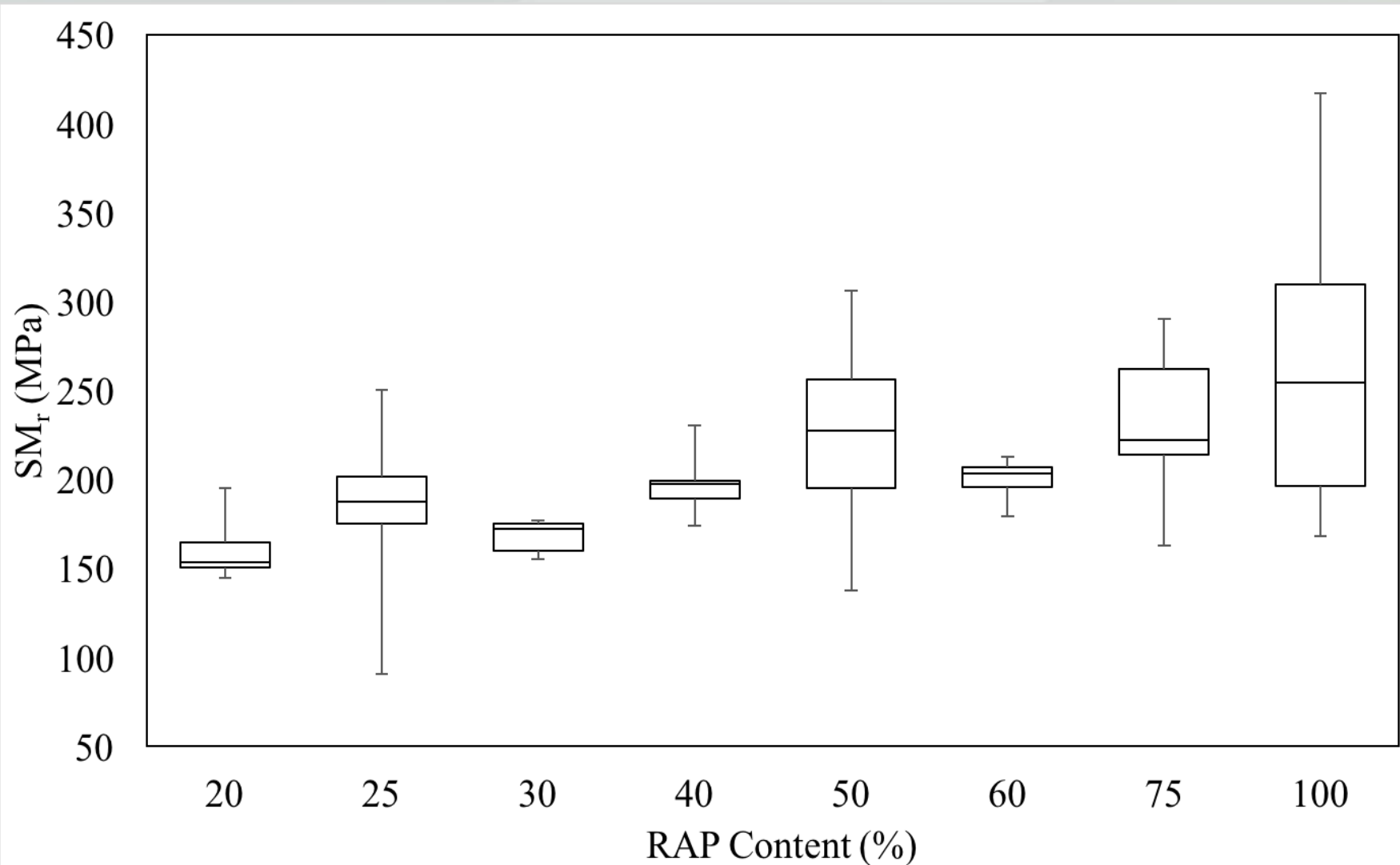
Hydraulic conductivity – RCA



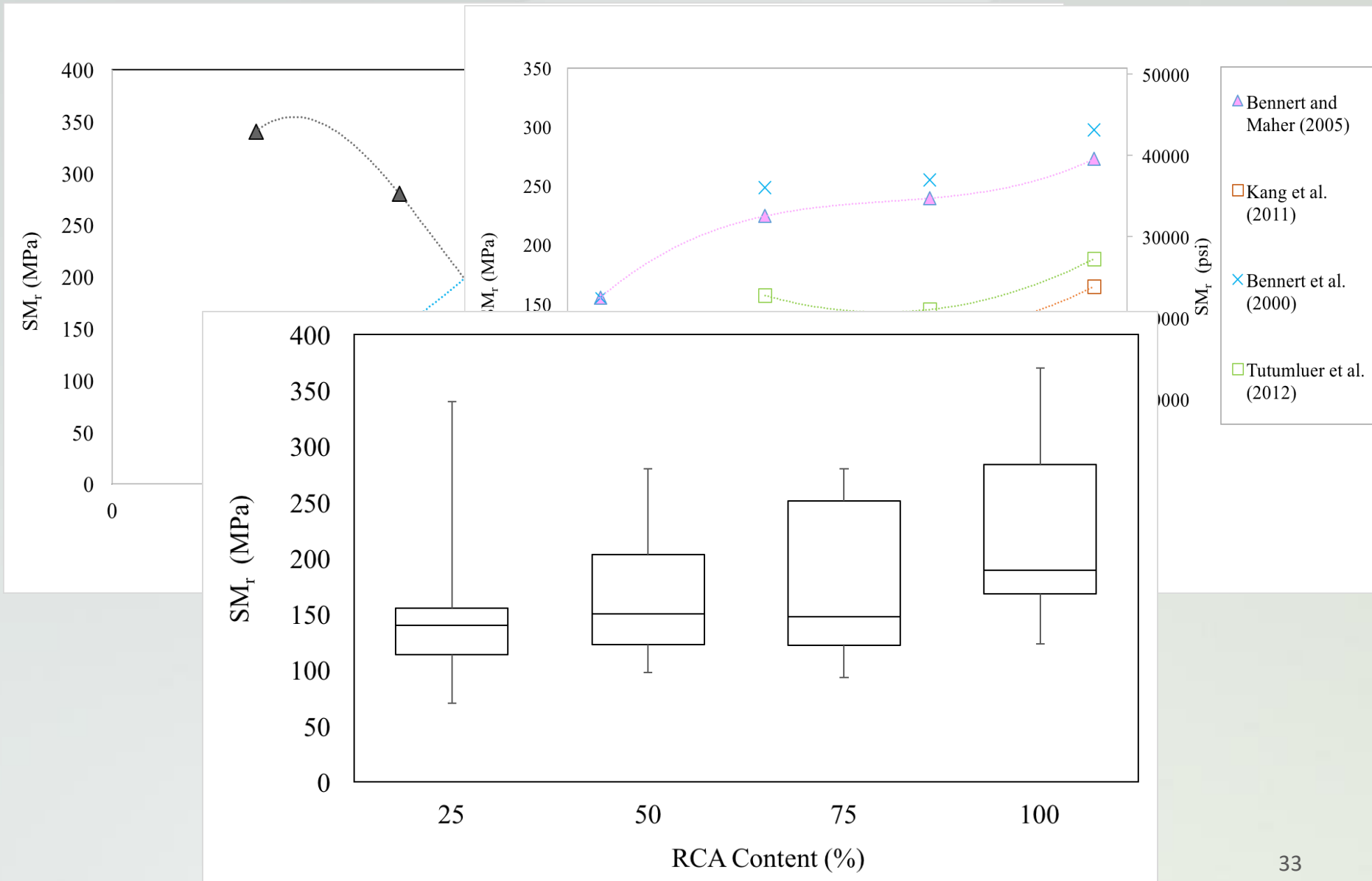
RAP content vs. SM_r – RAP



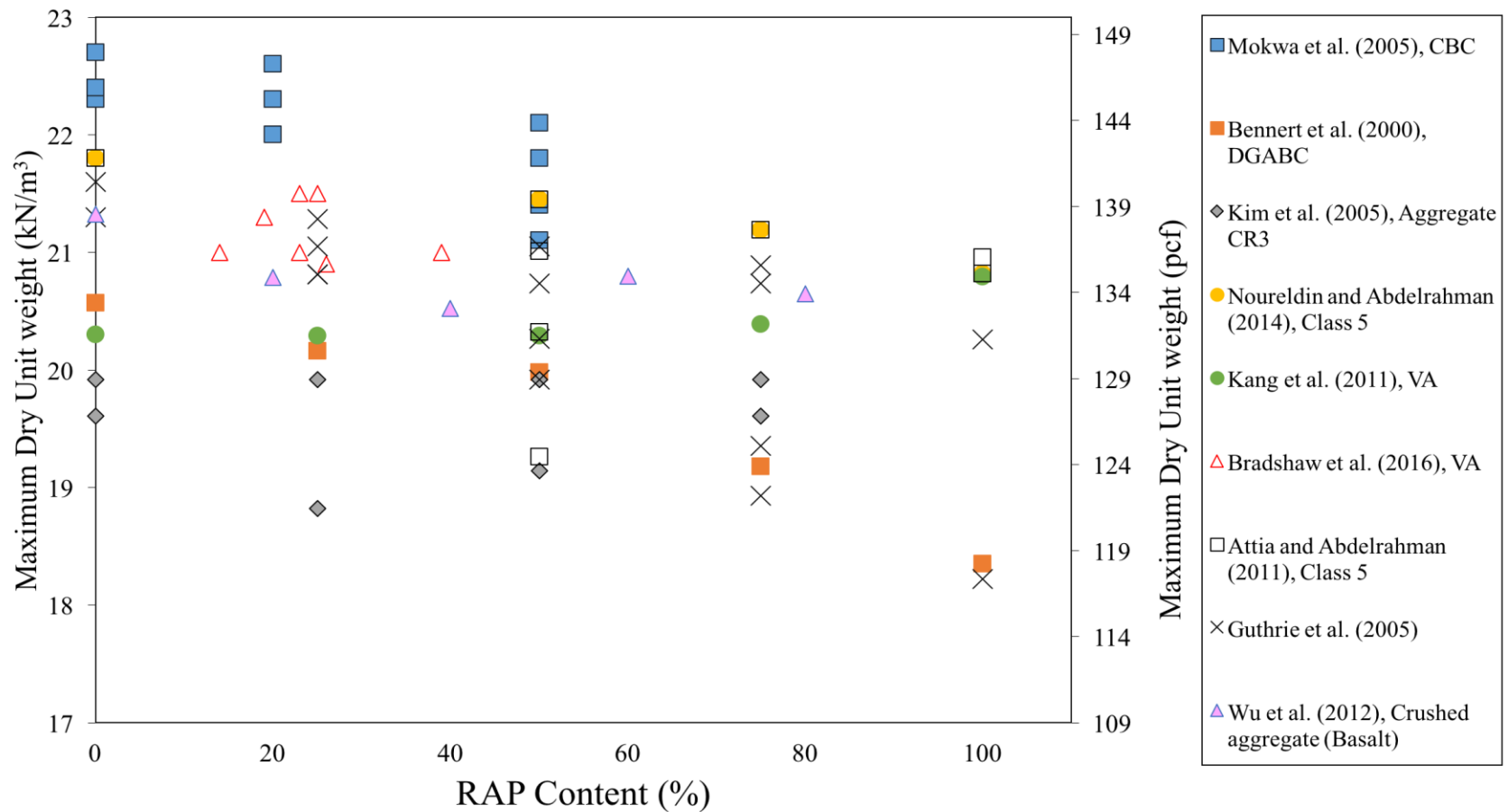
RAP content vs. $SM_r - RAP$



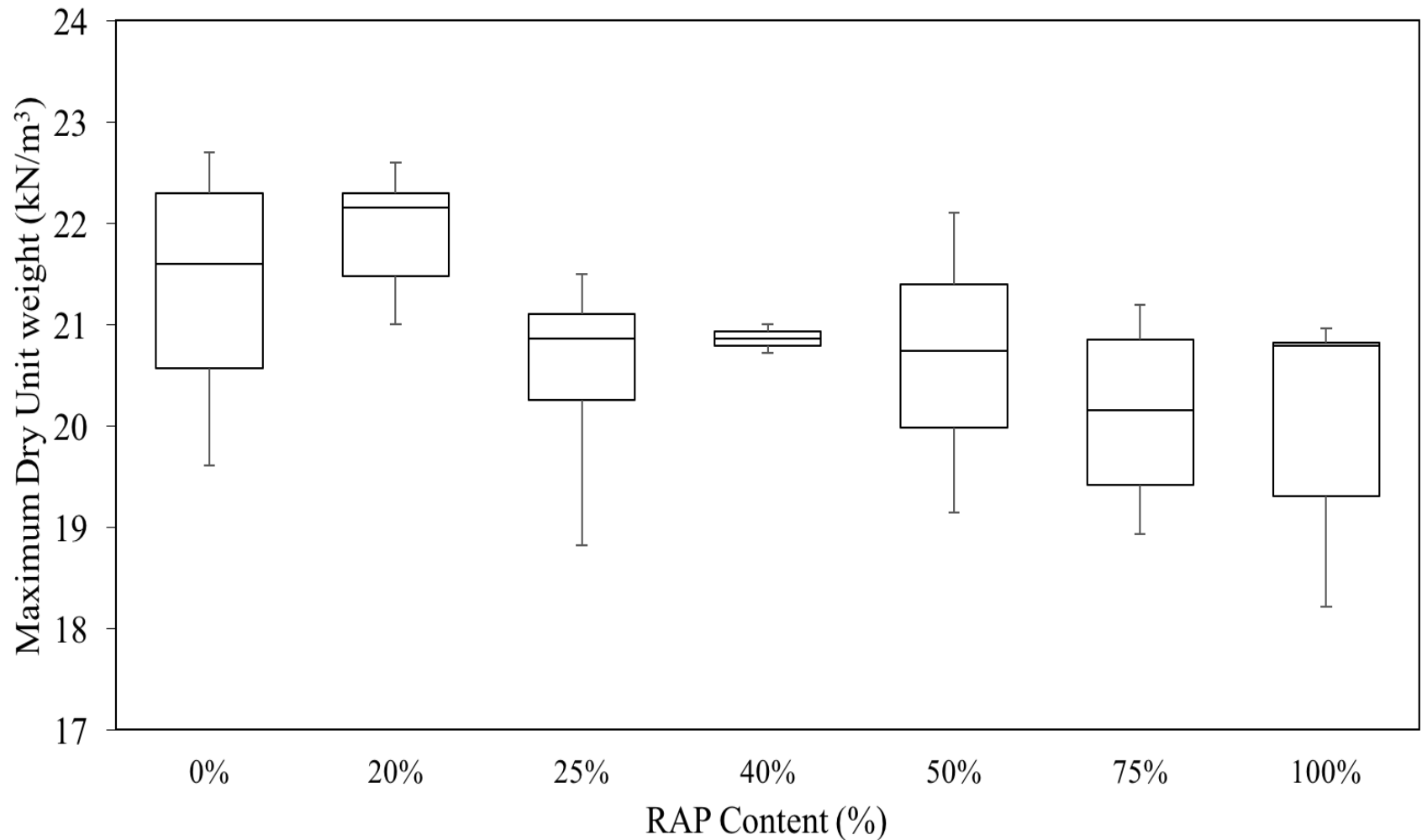
RCA content vs. SM_r – RCA



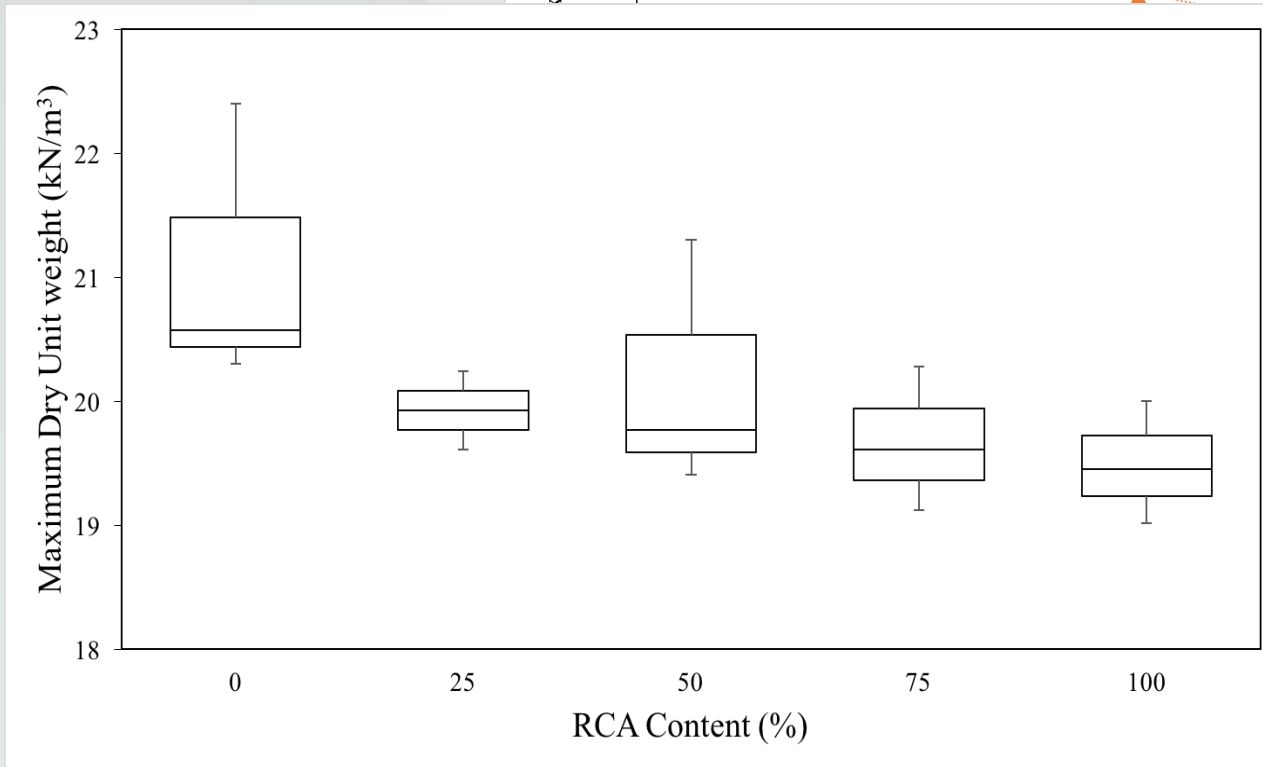
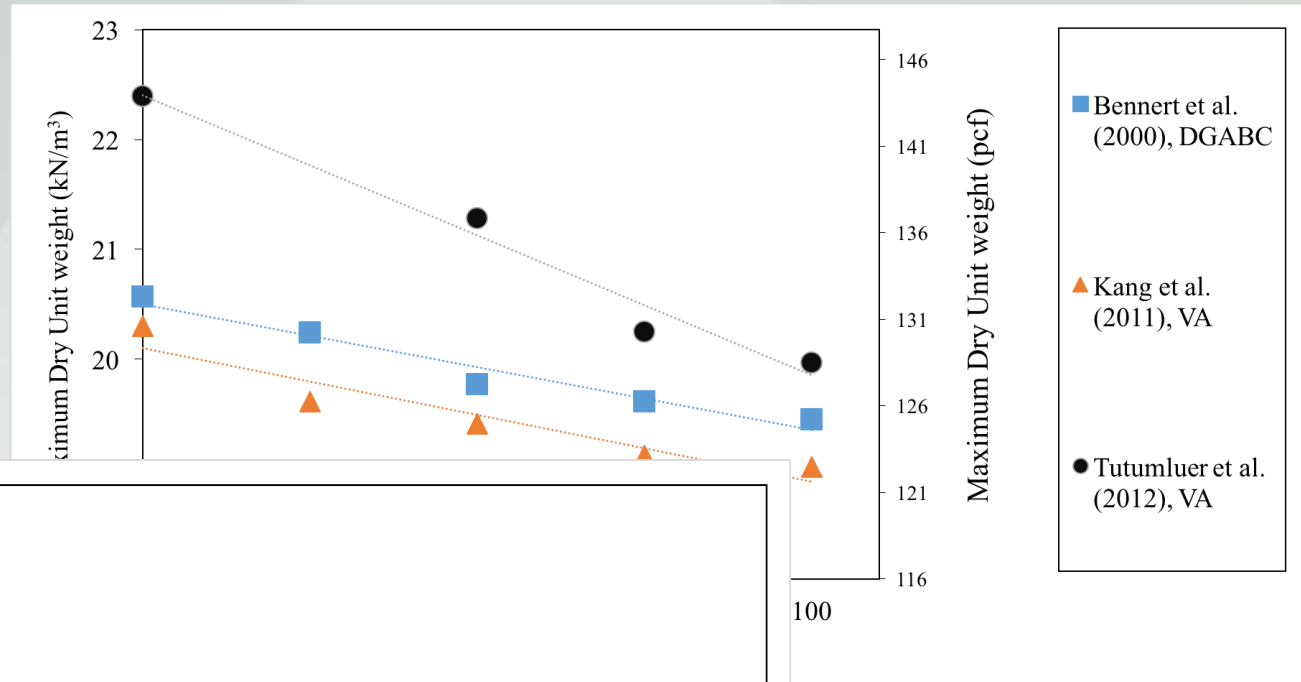
RAP content vs. MDU – RAP



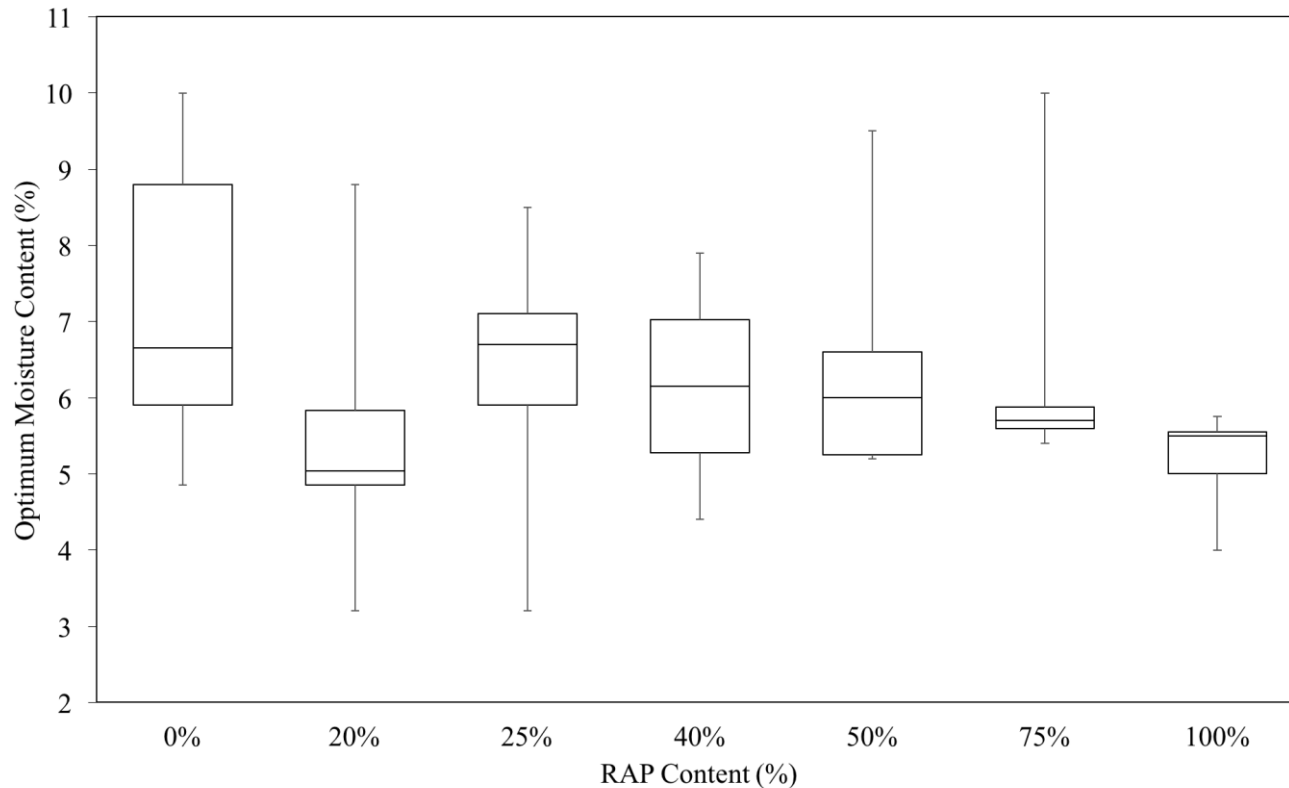
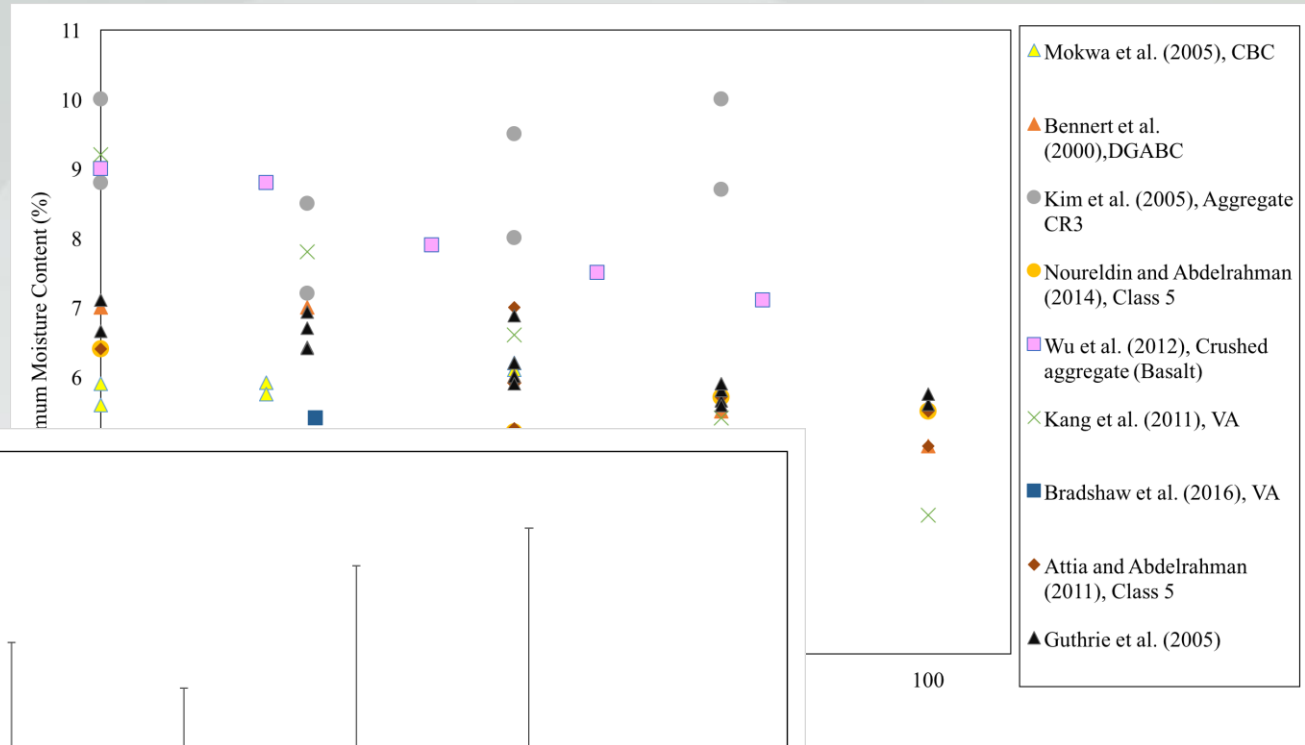
RAP content vs. MDU– RAP



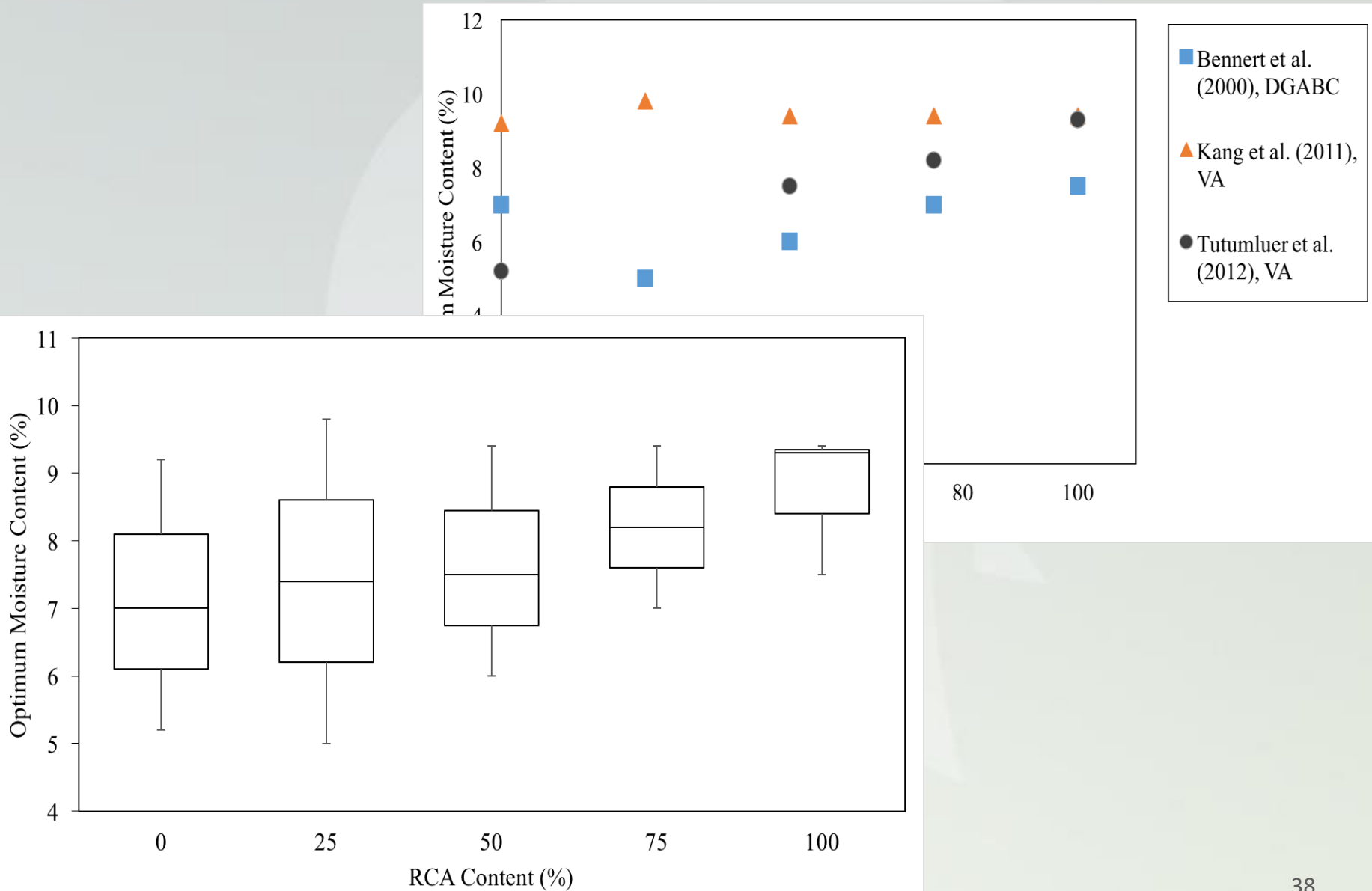
RCA content vs. MDU – RCA



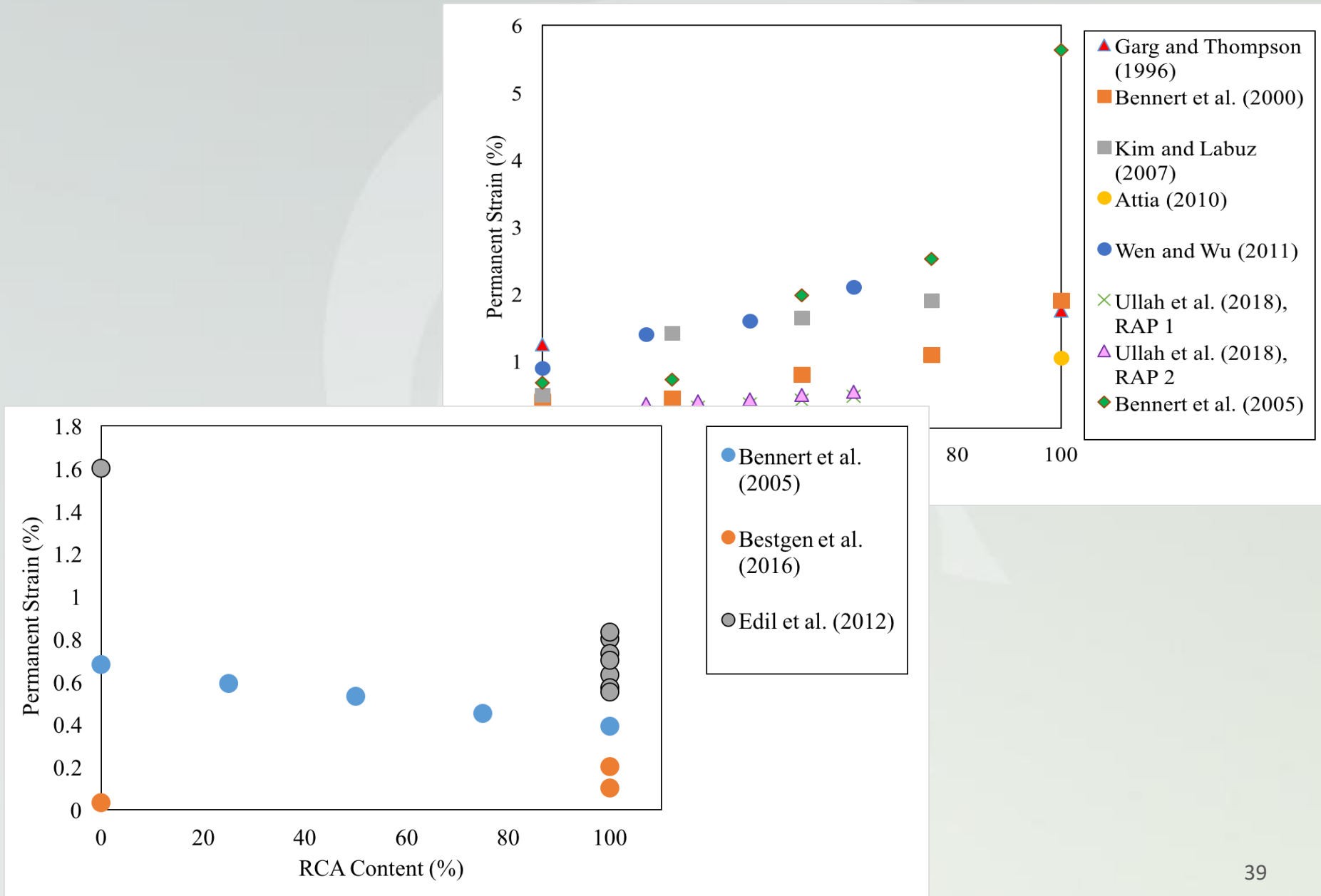
RAP content vs. OMC – RAP



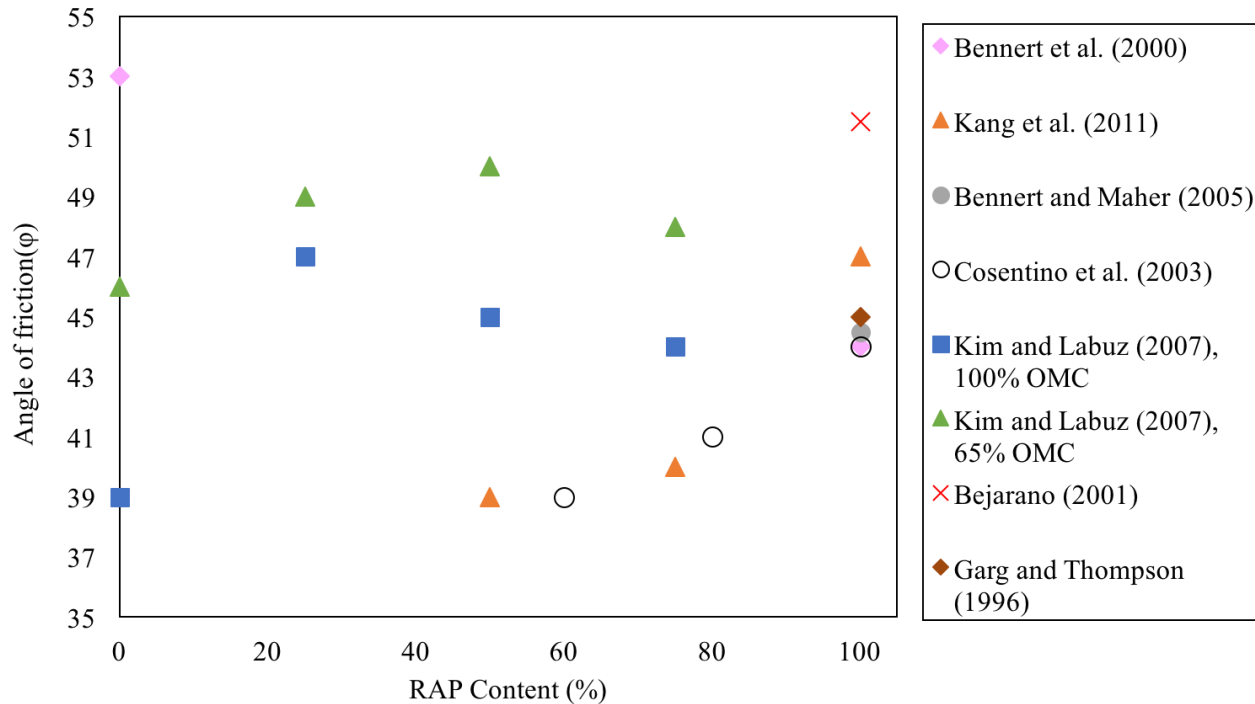
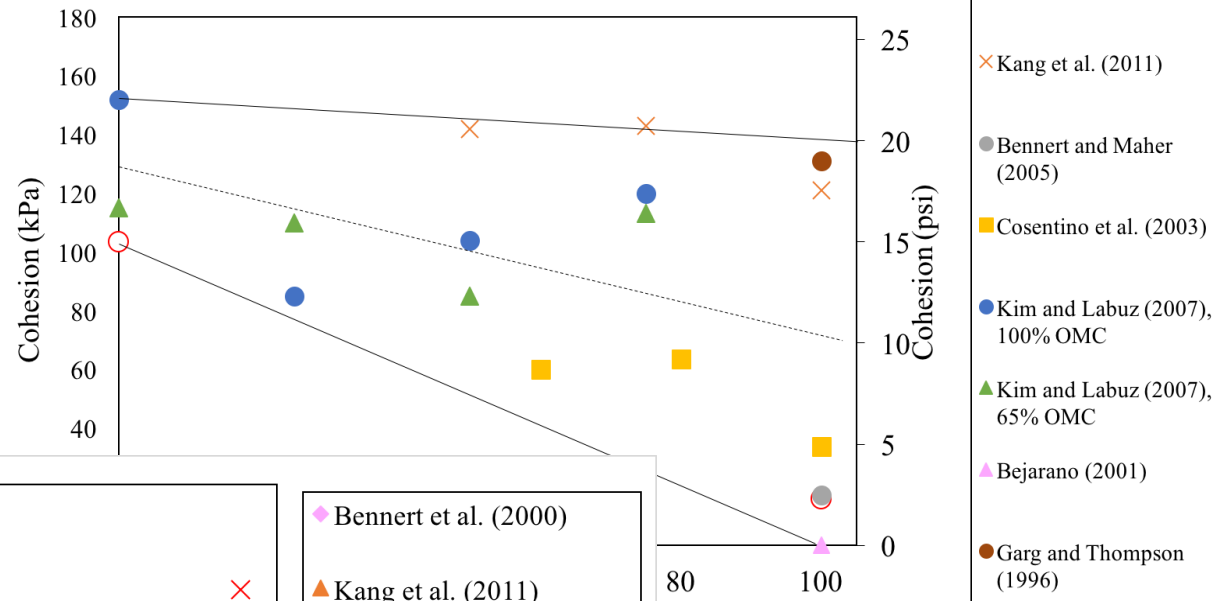
RCA content vs. OMC– RCA



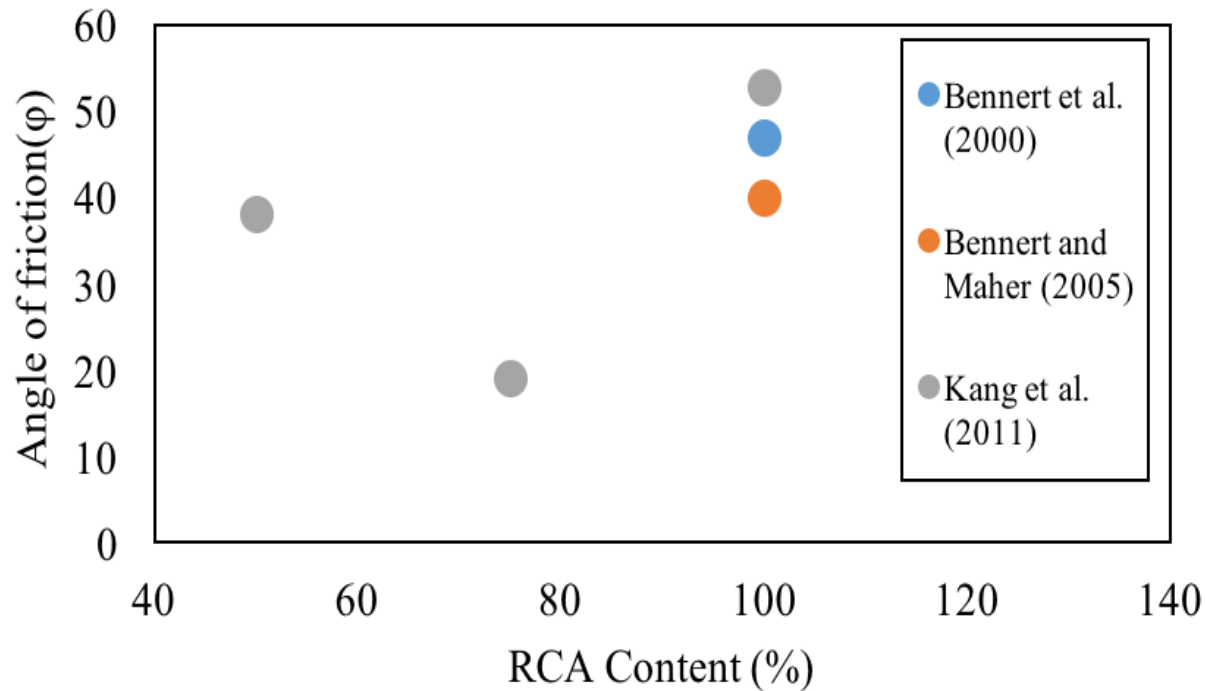
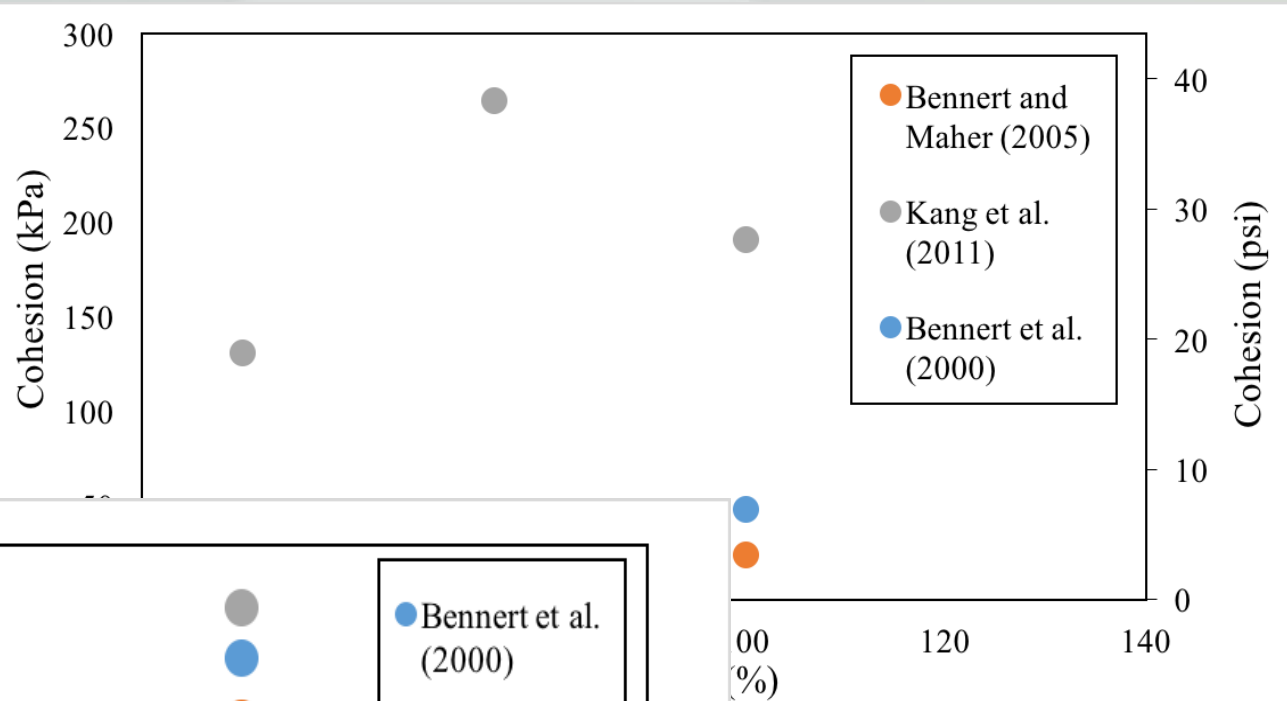
Permanent deformation



Shear strength – RAP



Shear strength – RCA



General Trends seen in RAPs

- Higher D_{30} , D_{60} and G/S , C_u $\Rightarrow$ Higher SM_r
- Higher fines content $\Rightarrow$ No effect on SM_r
- Higher OMC $\Rightarrow$ Lower SM_r
- Higher temperatures $\Rightarrow$ Lower SM_r unless thermal preloading is applied
- Higher D_{10} $\Rightarrow$ Higher hydraulic conductivity
- Higher fines contents $\Rightarrow$ Lower hydraulic conductivity
- Higher RAP content $\Rightarrow$ Higher SM_r , Lower CBR
- Higher RAP content $\Rightarrow$ Lower OMC of blends
- Higher RAP content $\Rightarrow$ Higher permanent strain

General Trends seen in RCAs

- Higher G/S, C_u ➡ Higher SM_r
- Higher fines content ➡ Lower SM_r
- Higher MDU ➡ Higher SM_r
- Higher OMC ➡ Lower SM_r
- Higher RCA content ➡ Lower hydraulic conductivity
- Higher RCA content ➡ Lower MDU
- Higher RCA content ➡ Higher OMC
- Higher RCA content ➡ Lower permanent deformation
- Higher temperature ➡ No trend in SM_r
- SM_r of RCA ➤ SM_r of virgin aggregates

Ongoing...

- Pavement ME analysis is being investigated accordingly with the minimum, maximum and median values of the database (SM_r , CBR, gradation, hydraulic conductivity and etc.) to check the status of pavement distresses.