Compaction Characteristics of Subbase Material using the Superpave Gyratory Compactor

Dr. Carlos Cary
Marie Lecorvaisier
Adam Bagriacik
Jerrett Clark
Robert Cohen
Kokeb Abera
Dr. Ali Daouadji
Dr. Beena Sukumaran

FAA Tech Transfer Conference, August 5-7, 2014

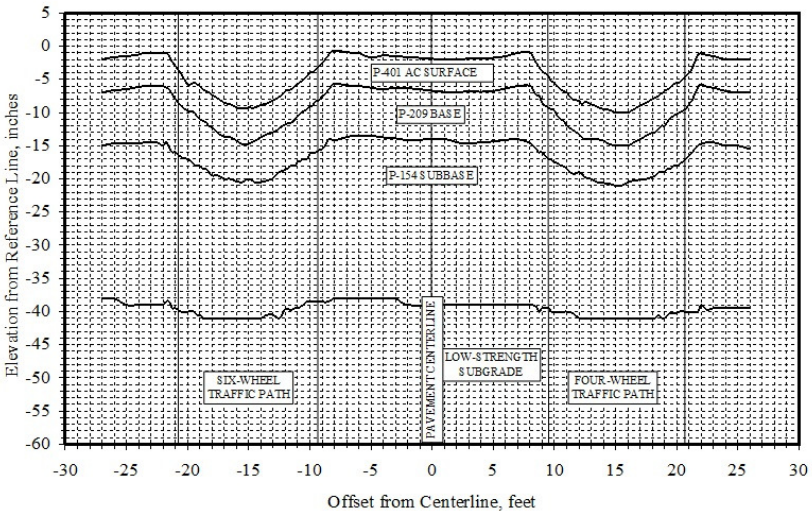
Rowan University

Outline

- Background and Objectives
- Comparison Between the Superpave Gyratory Compactor (SGC) and Modified Proctor
- P-154 and DGA Test Results
- Correlation of lab results with field data
- Conclusions

Rowan University

Background



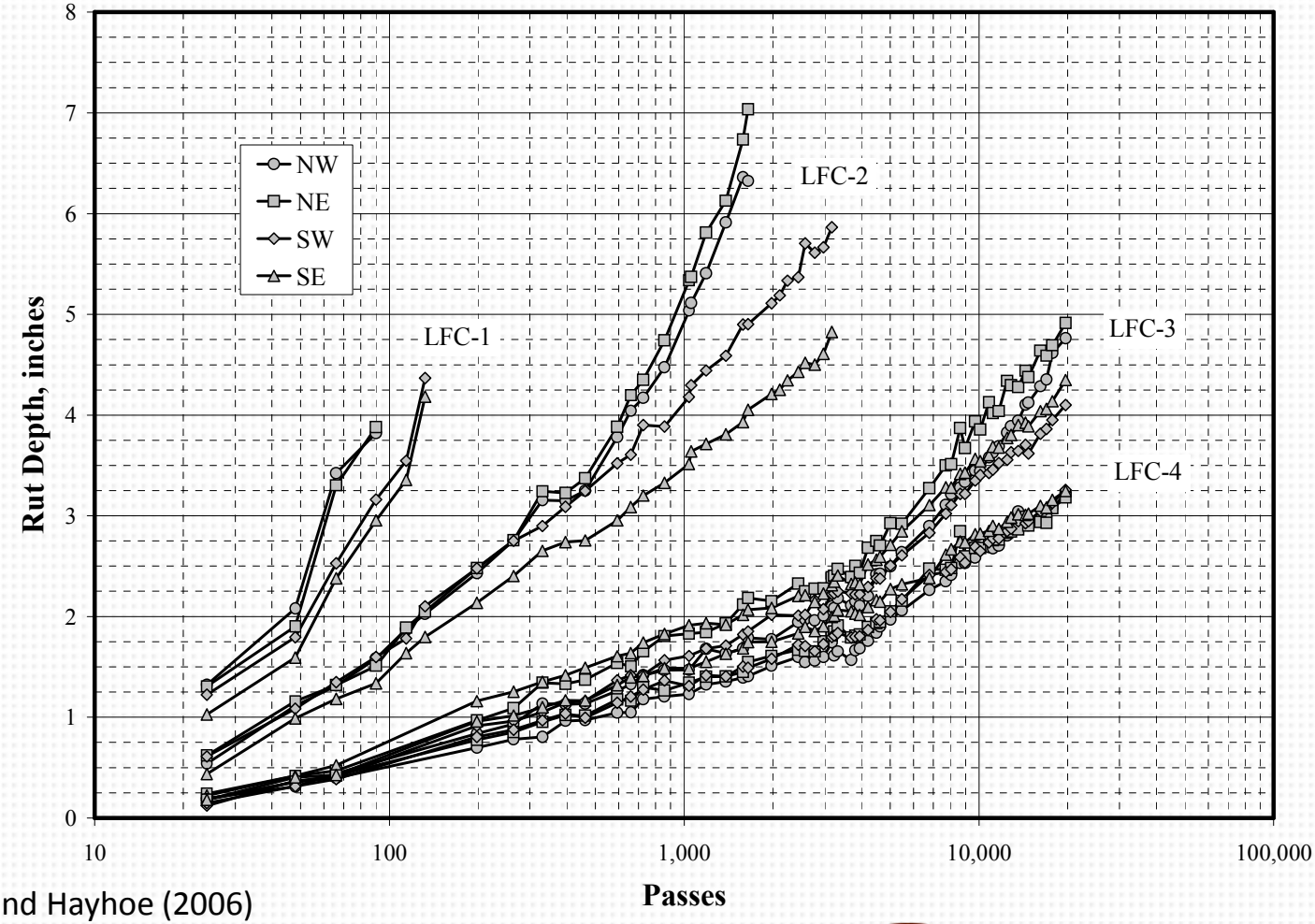
North wheel track of CC3 flexible pavements at 19,500 passes

Interface profile measurements in the LFC2 trafficked trench

Garg and Hayhoe (2006)

Rowan University

Background



Garg and Hayhoe (2006)

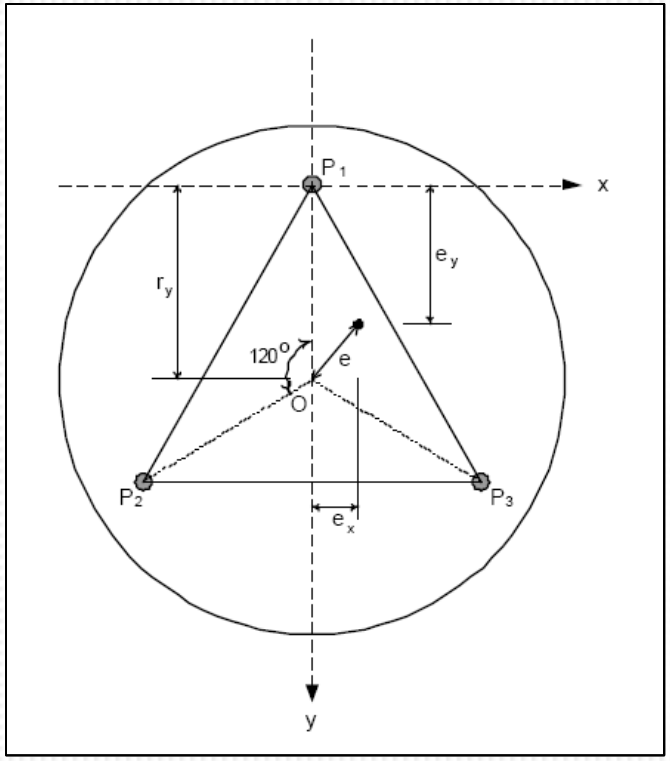
Rowan University

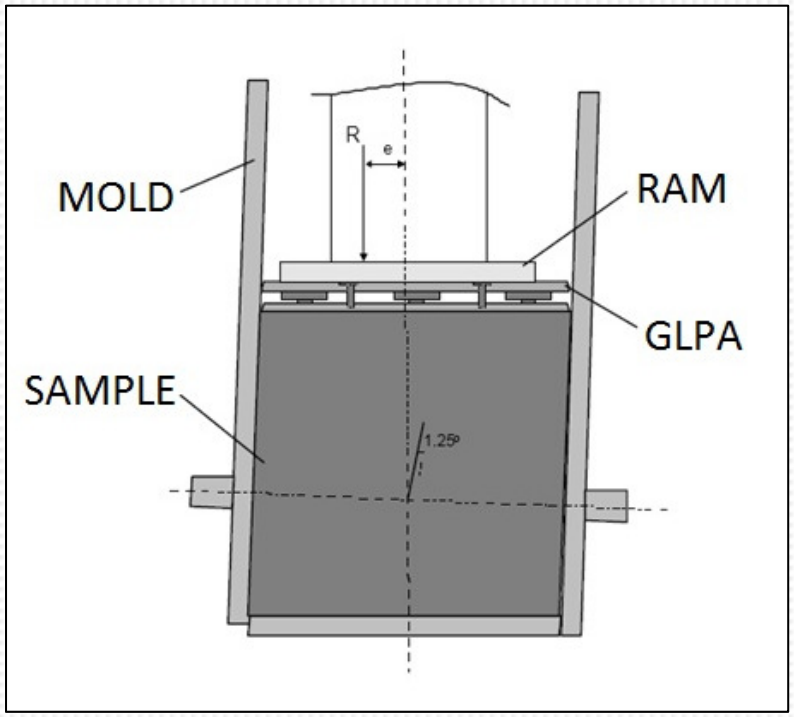
Gyratory Compactor

- Provides similar mechanism as construction equipment
- Variables
  - Angle - 1.25°
  - Pressure – 600 kPa
  - Number of Gyrations – 2400
- Sample Size – 3000 g

Rowan University

Compaction Energy





Mahmoud (2004)

Rowan University

Vertical Work

$$w_v = P\Delta h$$

- w_v = vertical work (in-lb)
- P = magnitude of resultant force
- Δh = change in height of sample (in)

Mahmoud (2004)

Shear Work

$$w = \frac{4Pe\theta}{Ah}$$

- w = shear work (in-lb)
- P = magnitude of the resultant force
- A = Cross Sectional Area (28.27 in^2)
- h = height of the specimen at any given gyration (in)
- e = eccentricity of resultant force
- θ = angle of tilt (1.25°)

Mahmoud (2004)

Rowan University

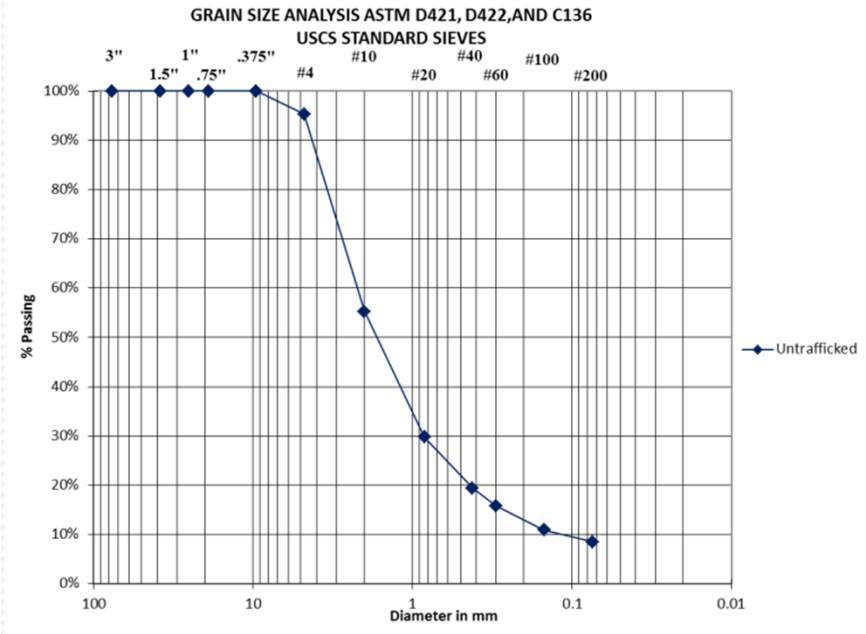
Objectives

- To evaluate the use of the SGC over the Modified Proctor method as a compaction standard to prevent excessive compaction during heavy aircraft trafficking
- To attempt to develop an energy based method for predicting aggregate performance during construction and trafficking using the SGC
- To determine the crushing mechanisms promoting excessive compaction of aggregates

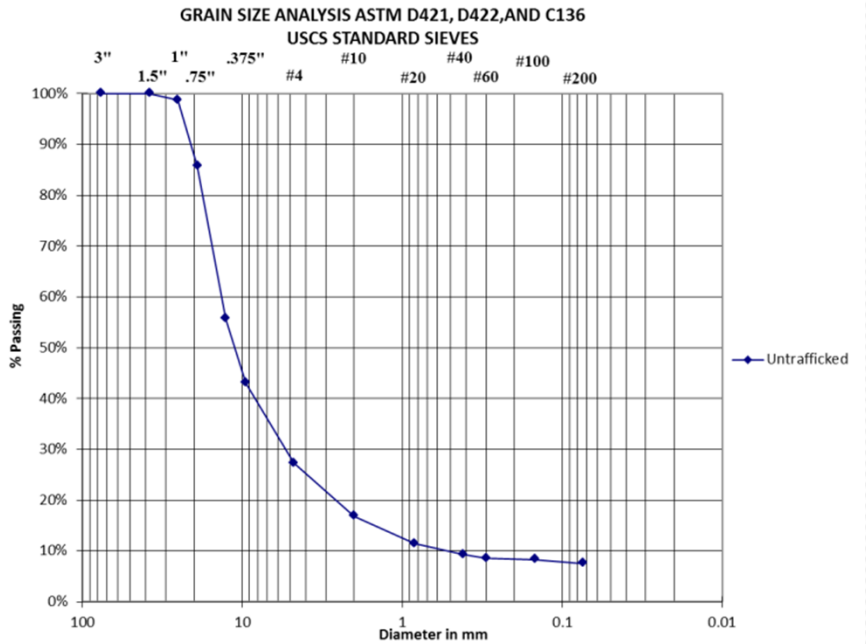
Rowan University

Materials

P-154

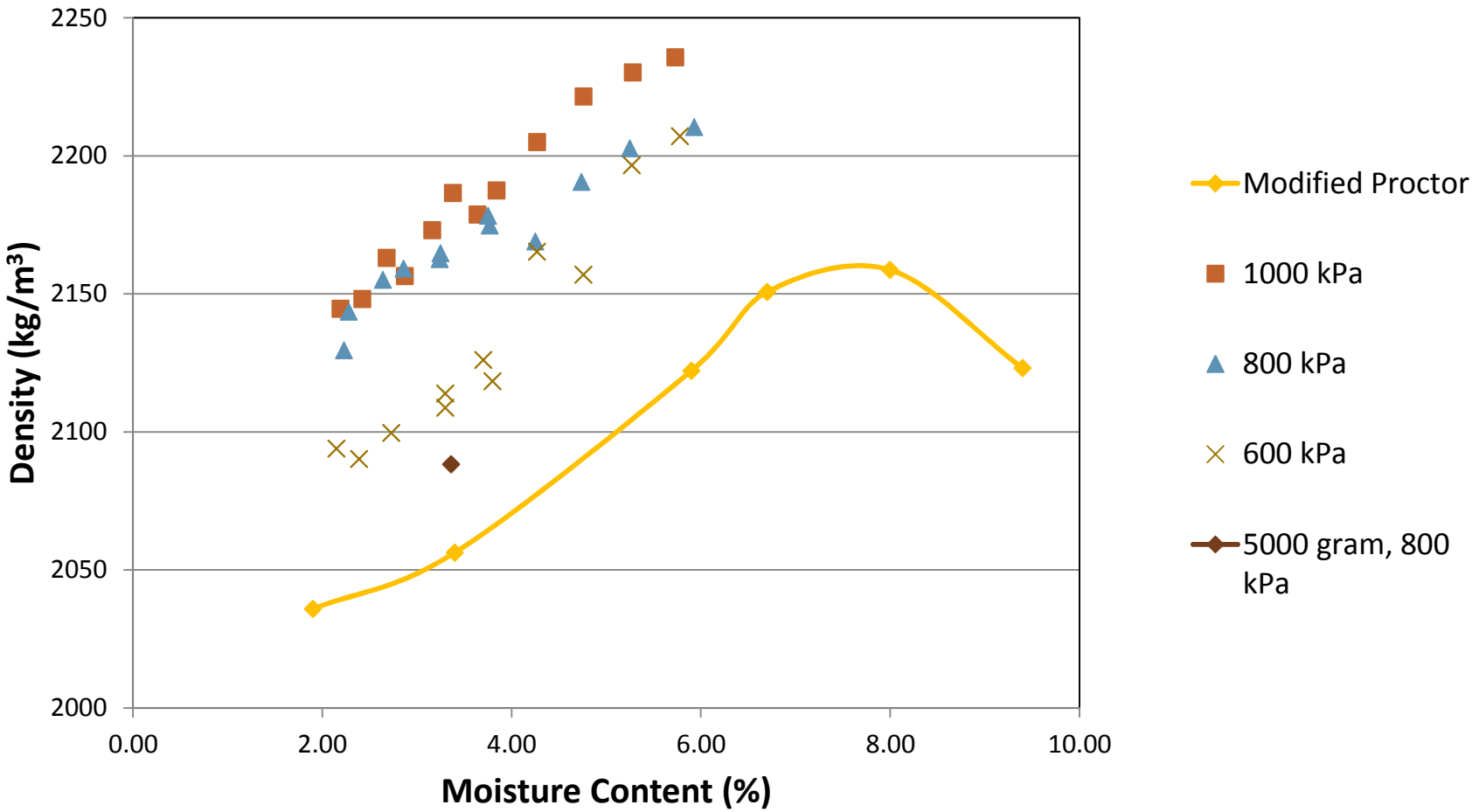


DGA



Rowan University

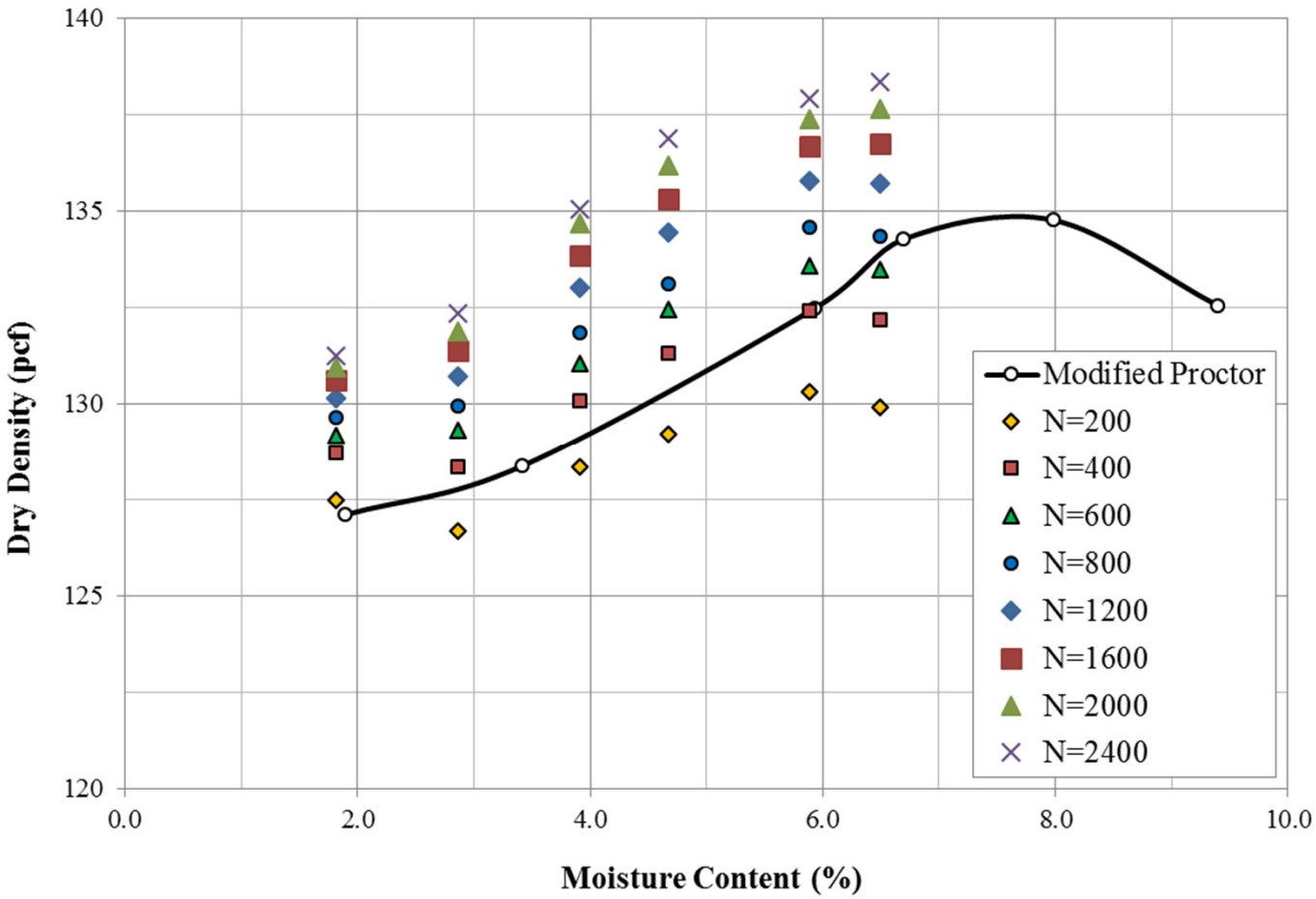
SGC Density at 800 Gyrations and Modified Proctor Data P-154



Rowan University

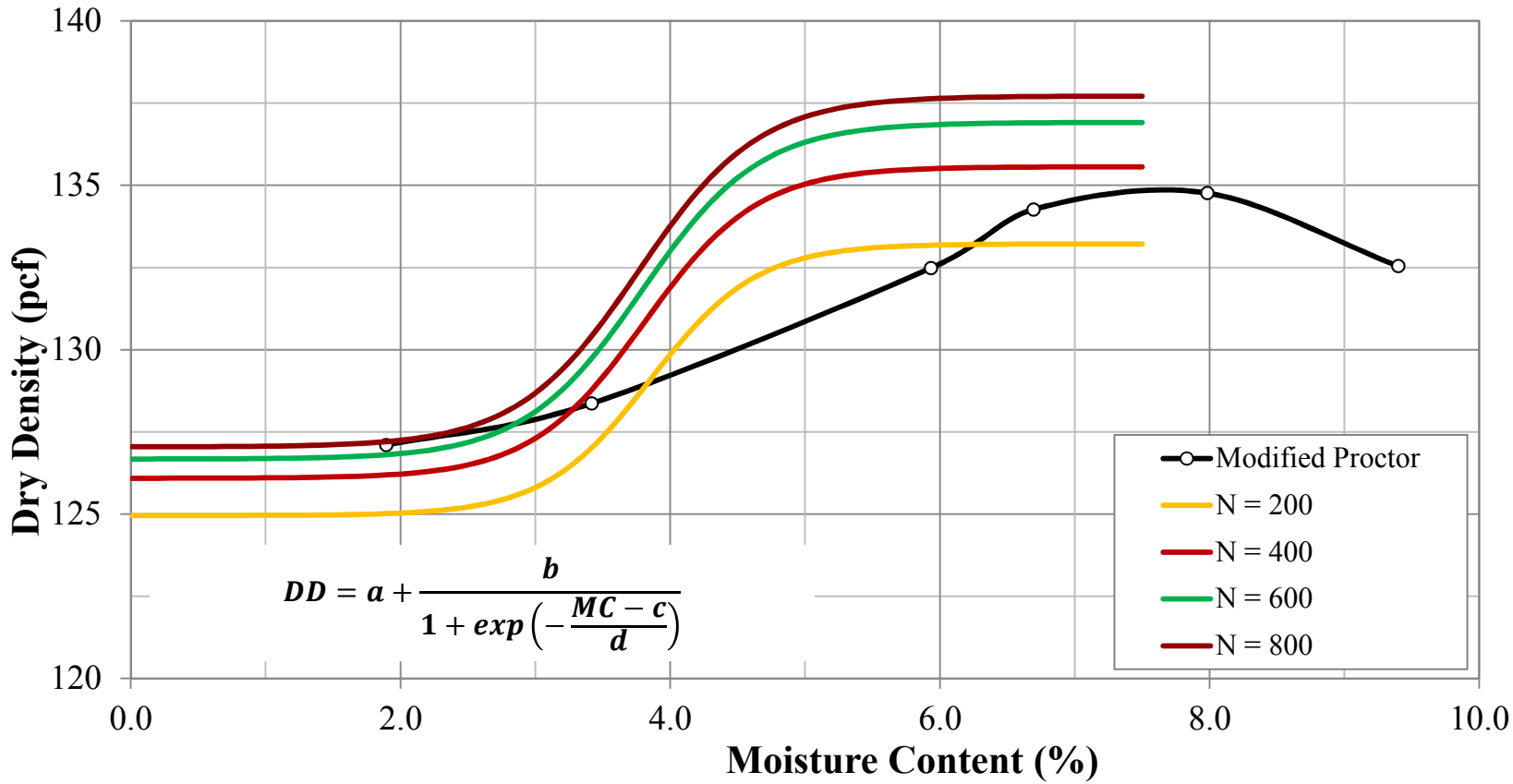
Development of Energy Based Method – P-154

600 kPa Densities at 200 Gyration Increments



Rowan University

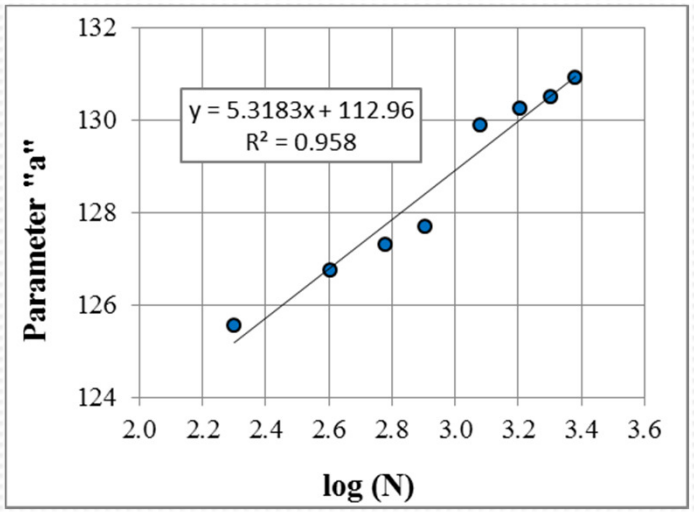
Development of Energy Based Method – P-154

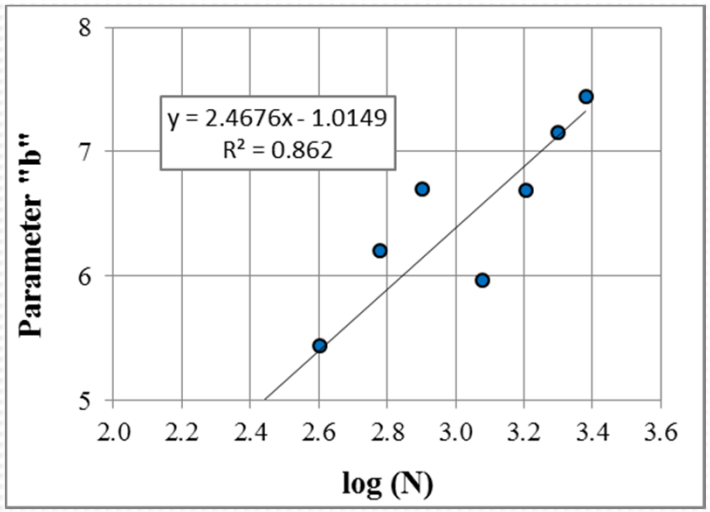


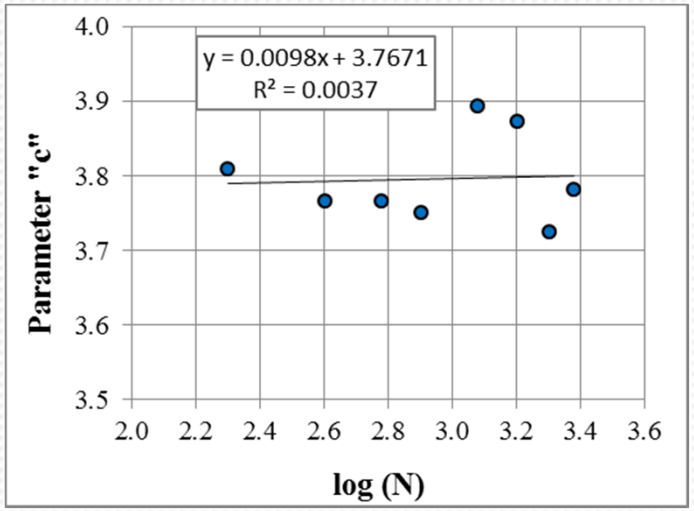
$$DD = a + \frac{b}{1 + exp\left(-\frac{MC - c}{d}\right)}$$

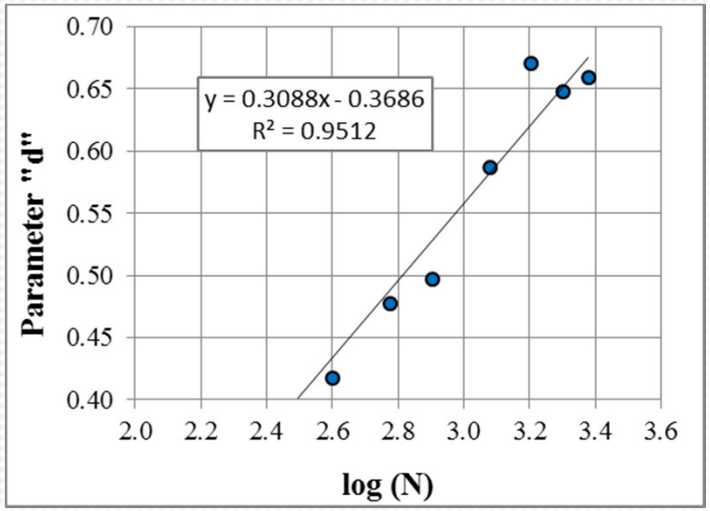
Rowan University

Development of Energy Based Method – P-154



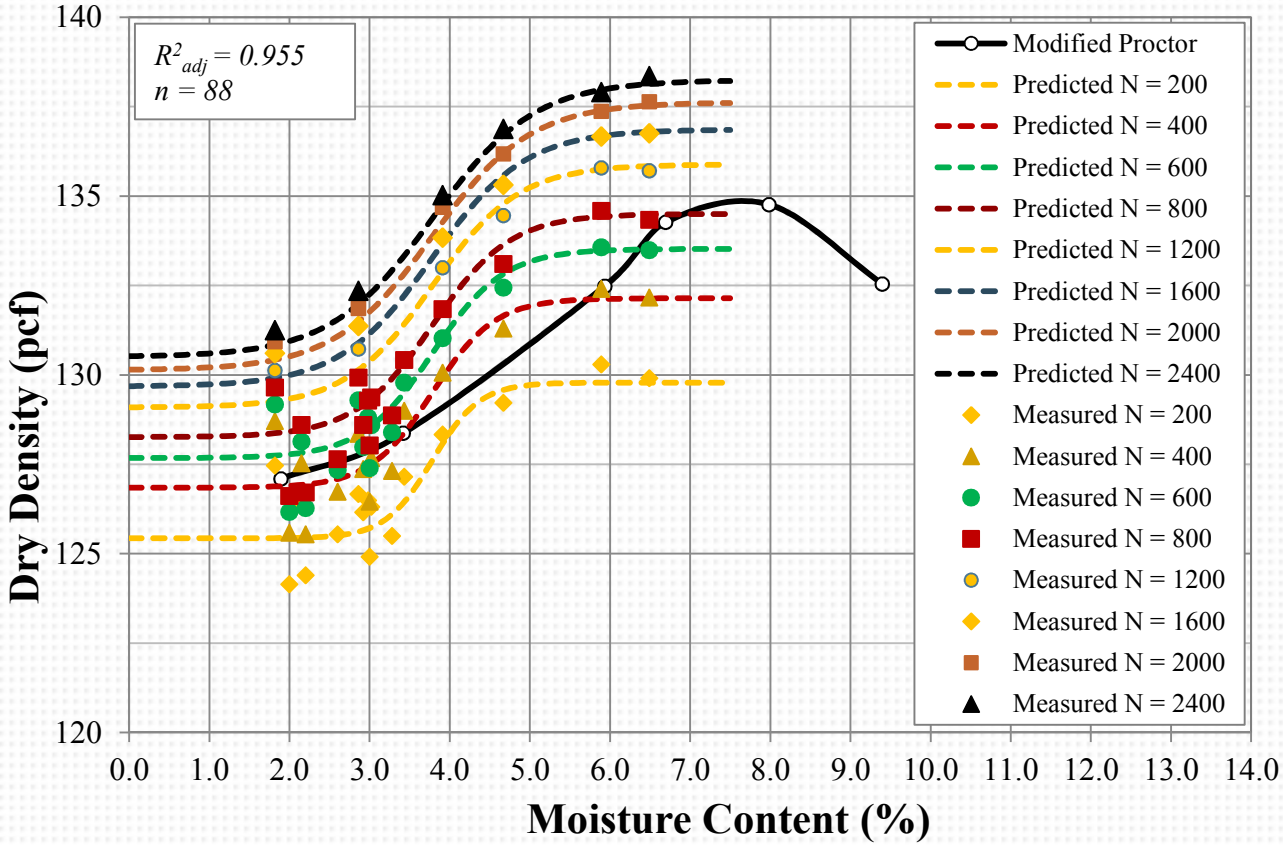






Rowan University

Development of Energy Based Method – P-154



$$DD = (\alpha \log N + \beta) + \frac{(\gamma \log N + \delta)}{1 + exp\left(-\frac{MC - (\mu)}{(\varphi \log N + \omega)}\right)}$$

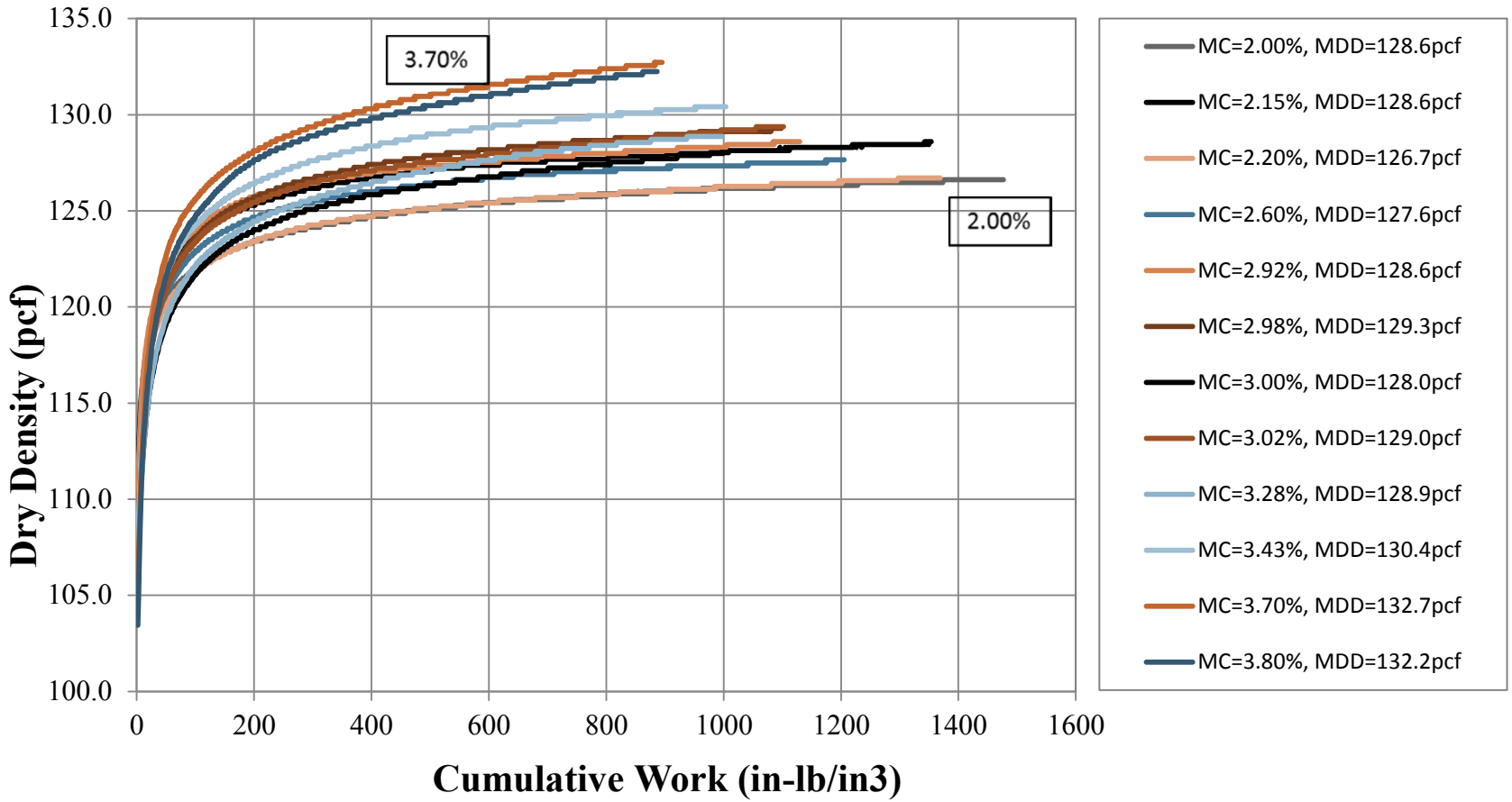
$\alpha = 5.3183$, $\beta = 112.96$, $\gamma = 2.4676$, $\delta = -1.0149$,
$\mu = 3.7671$, $\varphi = 0.3088$, $\omega = -0.3686$

*Values will change as material properties change

Rowan University

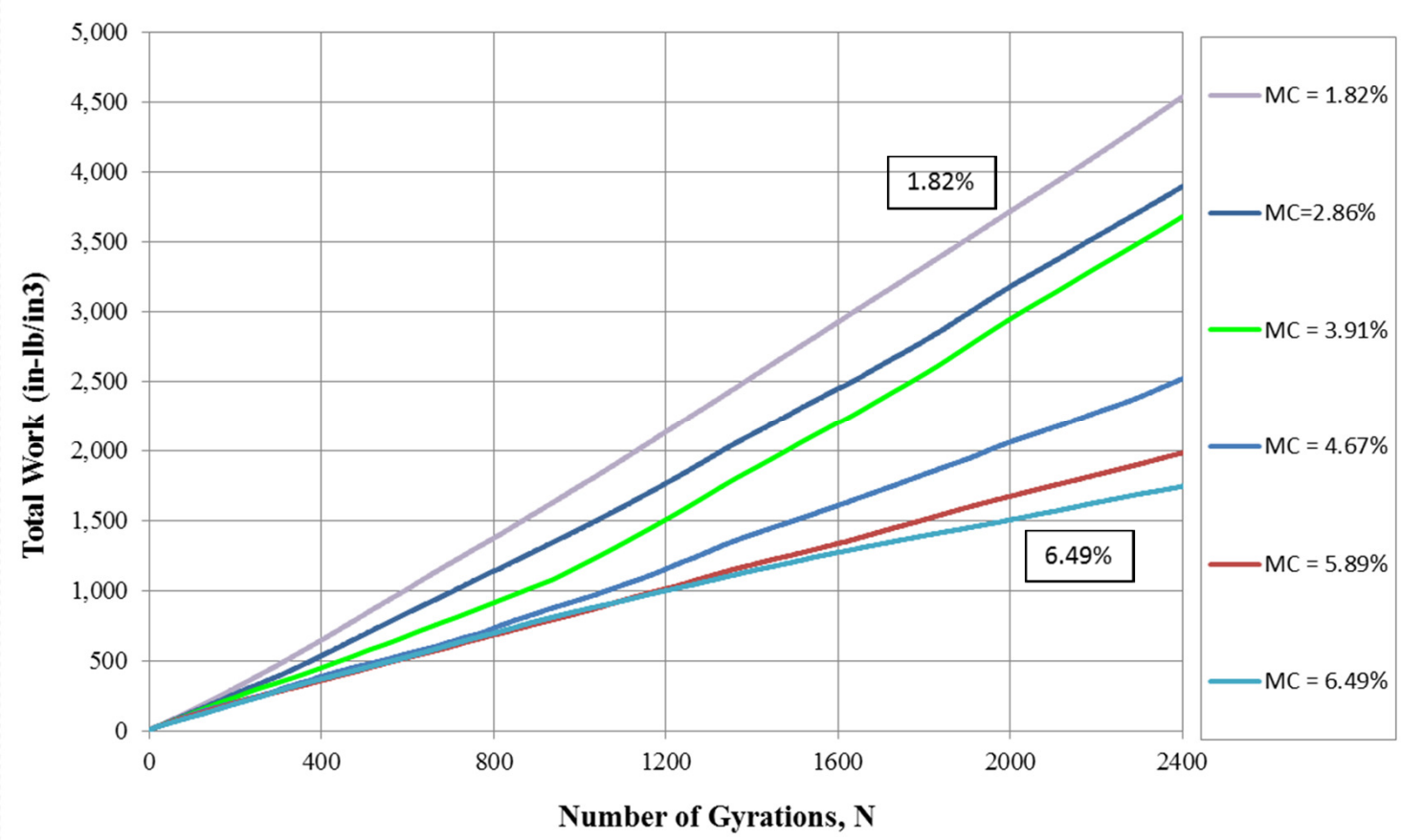
Development of Energy Based Method – P-154

Dry Density and Total Energy



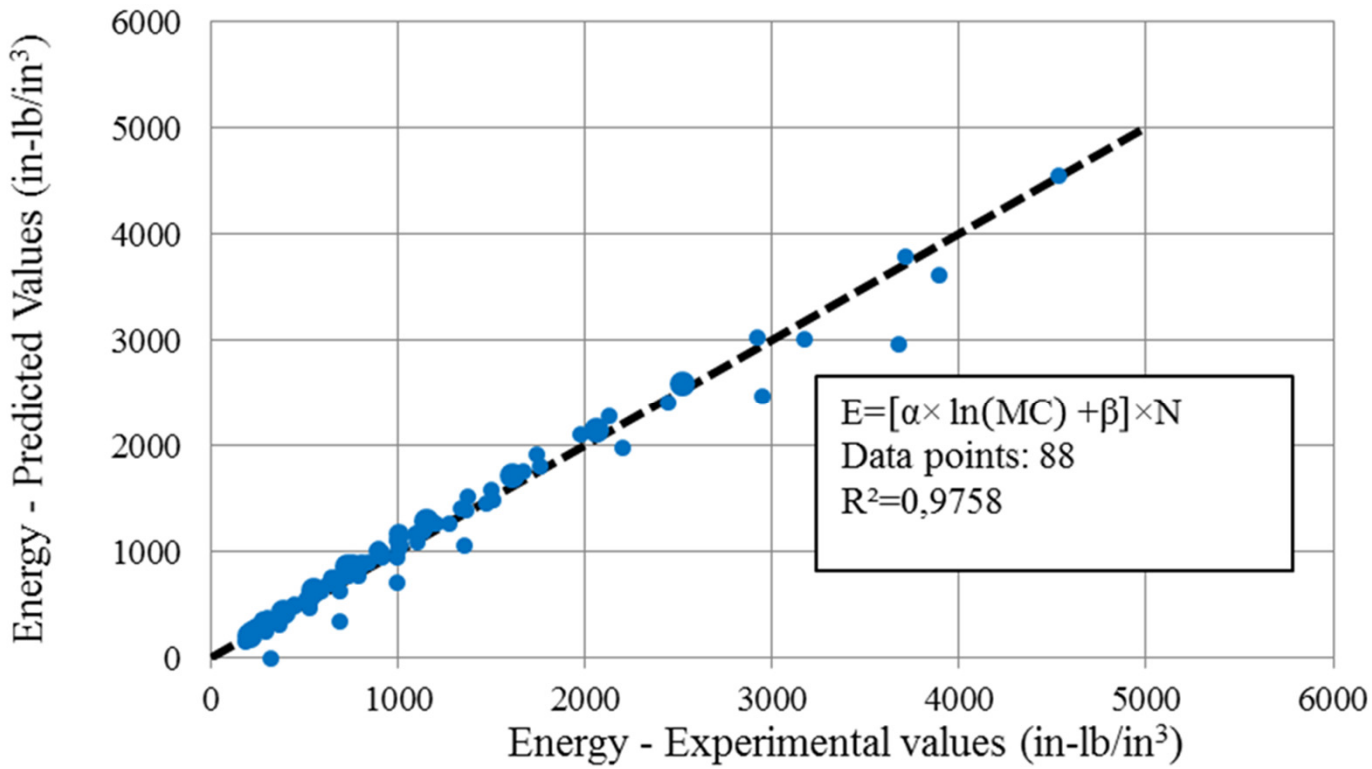
Rowan University

Development of Energy Based Method – P-154 Gyrations and Total Work



Rowan University

Development of Energy Based Method – P-154 Energy Prediction

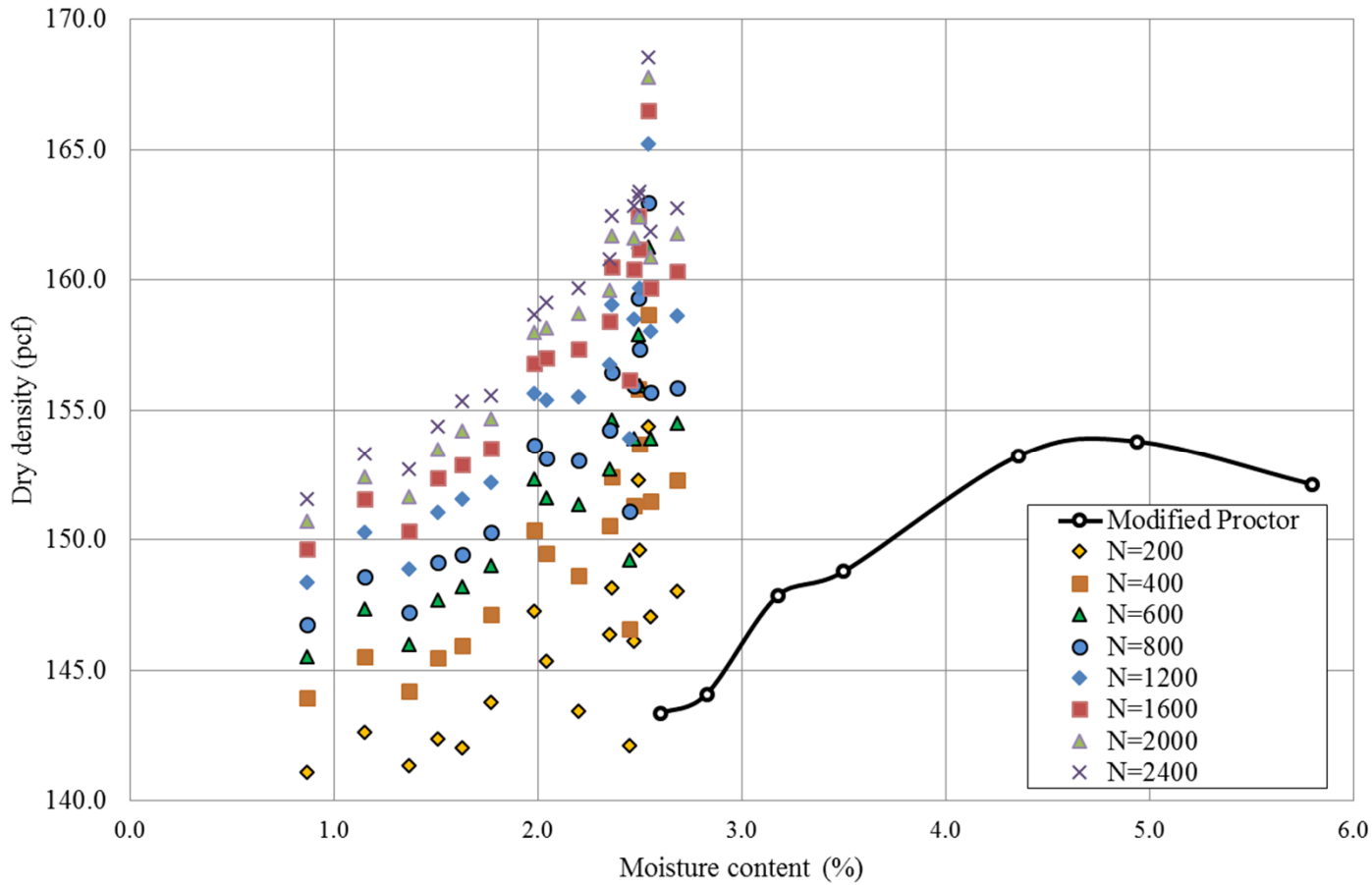


Where $\alpha = -0.8861$ and $\beta = 2.4149$

Rowan University

Development of Energy Based Method – DGA

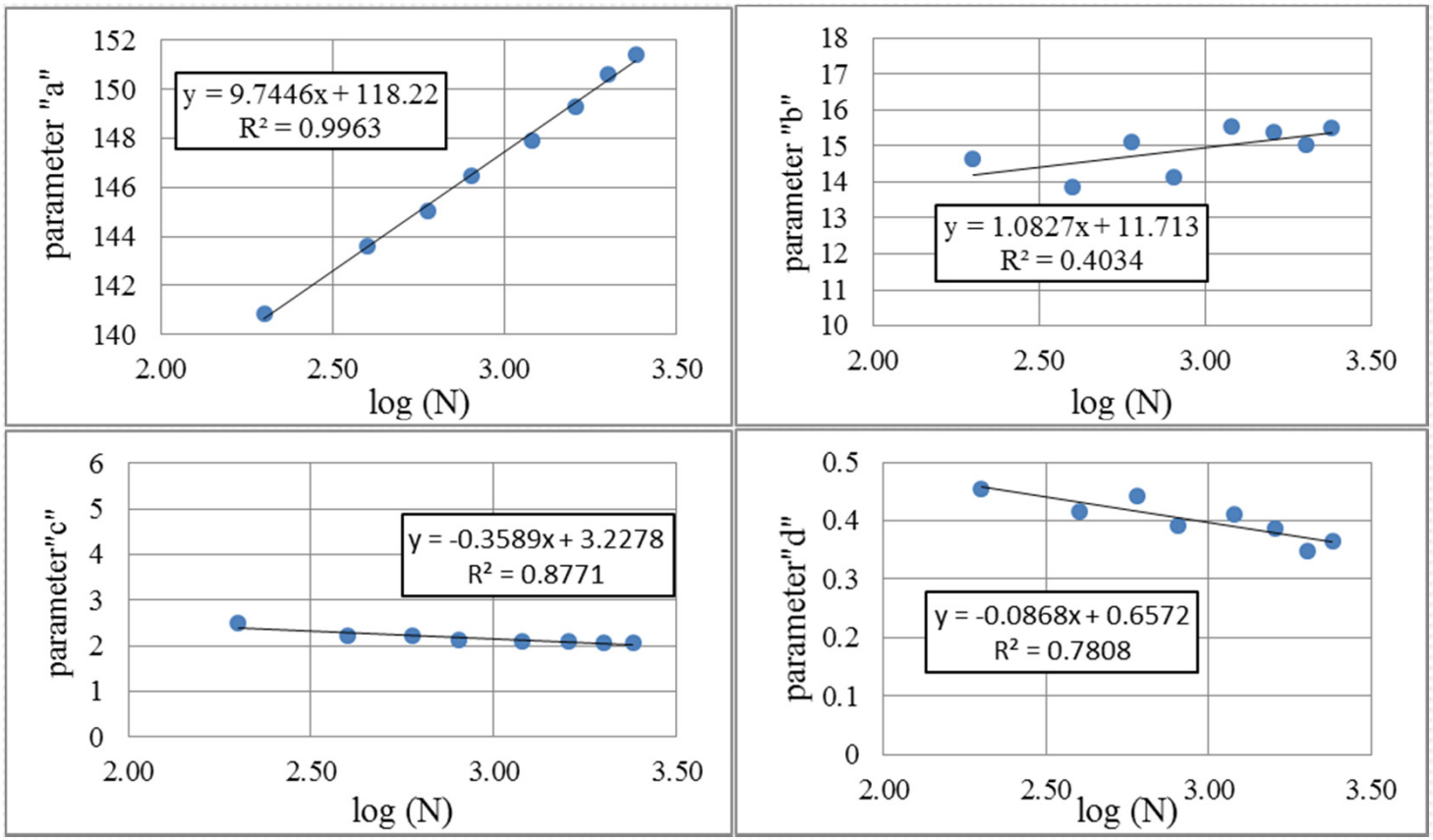
600 kPa Densities at 200 Gyration Increments



$$DD = a + \frac{b}{1 + exp\left(-\frac{MC - c}{d}\right)}$$

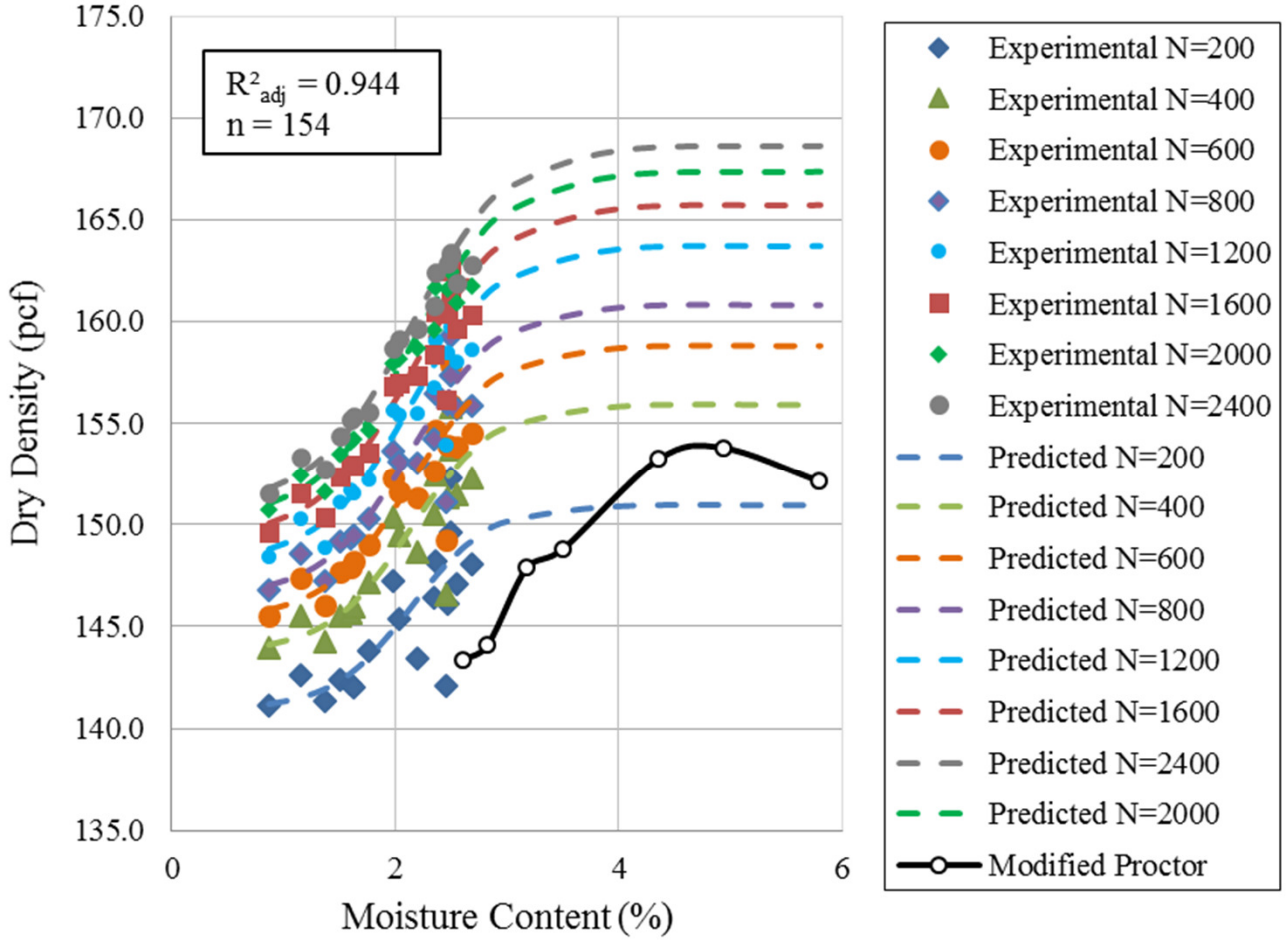
Rowan University

Development of Energy Based Method – DGA



Rowan University

Development of Energy Based Method – DGA

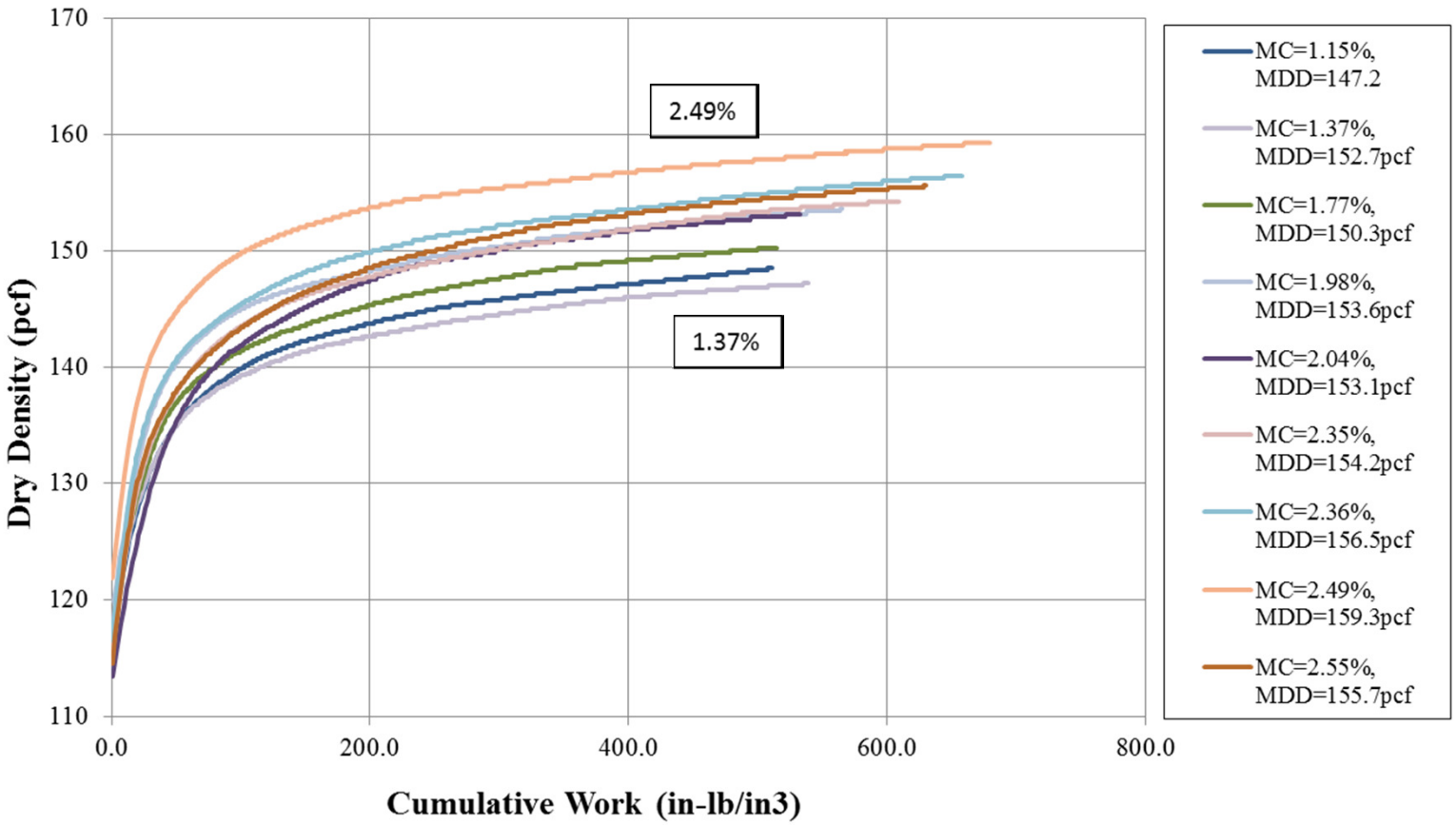


$$DD = (\alpha \log N + \beta) + \frac{(\gamma \log N + \delta)}{1 + exp\left(-\frac{MC - (\mu)}{(\varphi log(N) + \omega)}\right)}$$

$\alpha = 9.7446$, $\beta = 118.22$, $\gamma = 1.0827$, $\delta = 11.713$,
$\mu = 3.2278$; $\varphi = -0.0868$, $\omega = 0.6572$

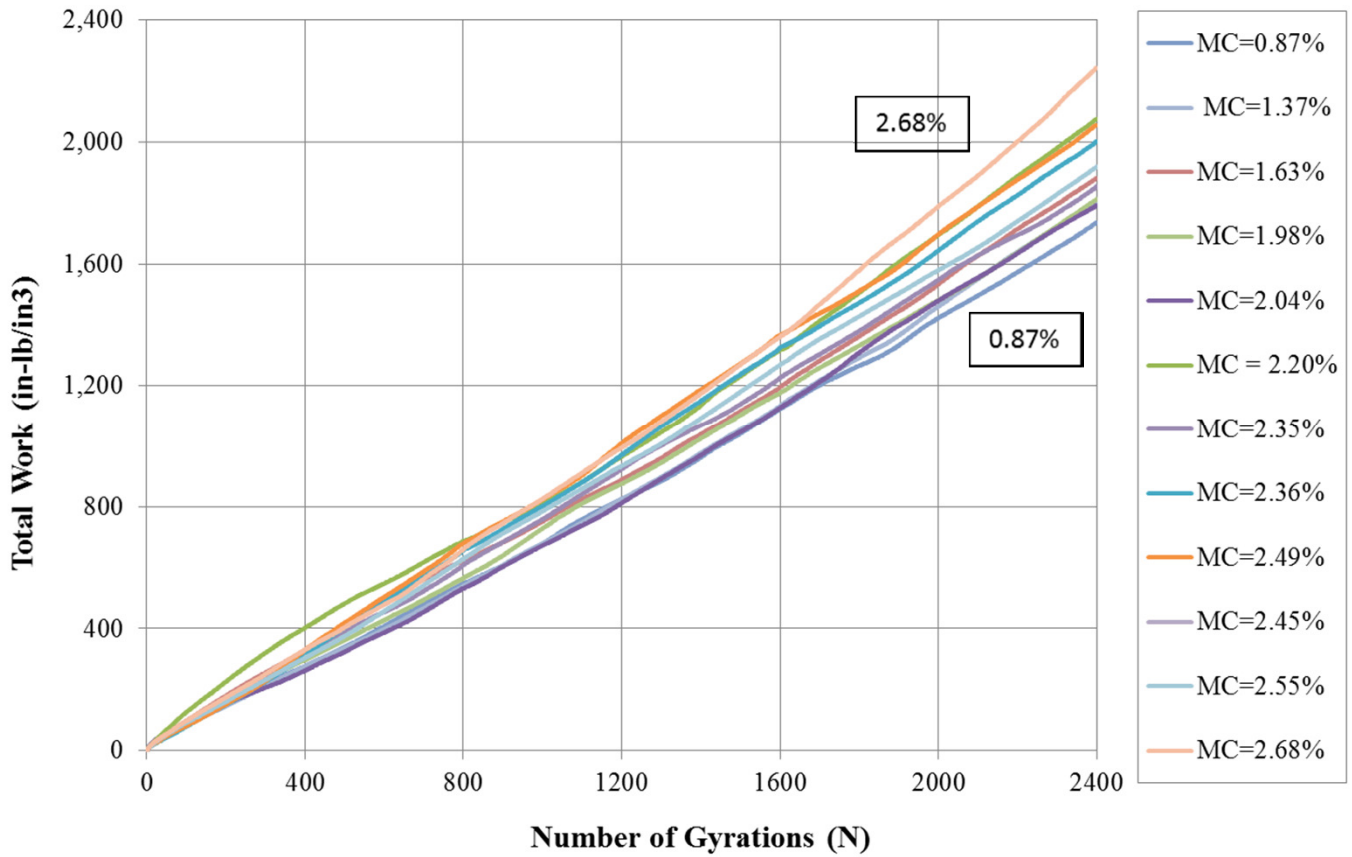
Rowan University

Development of Energy Based Method – DGA Dry Density and Total Energy



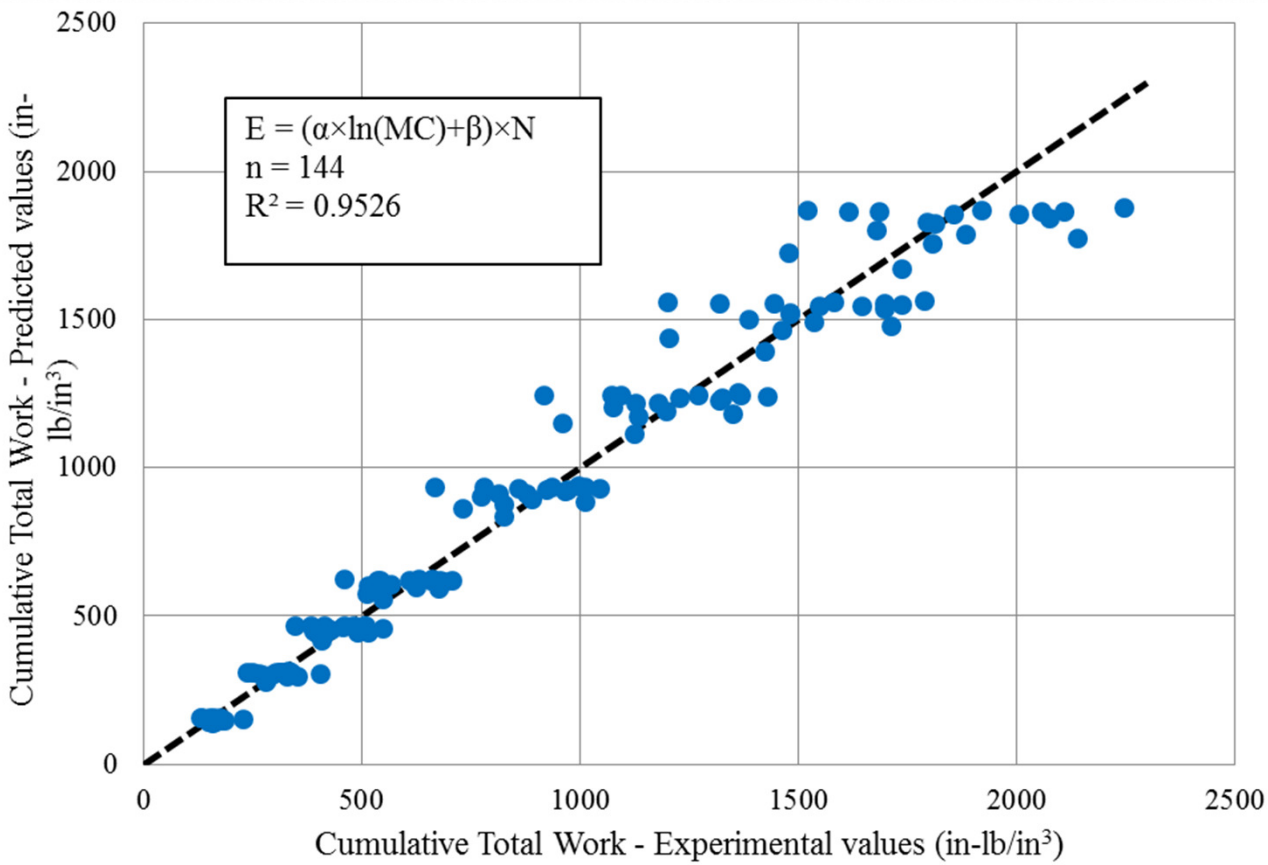
Rowan University

Development of Energy Based Method – DGA Gyrations and Total Work



Rowan University

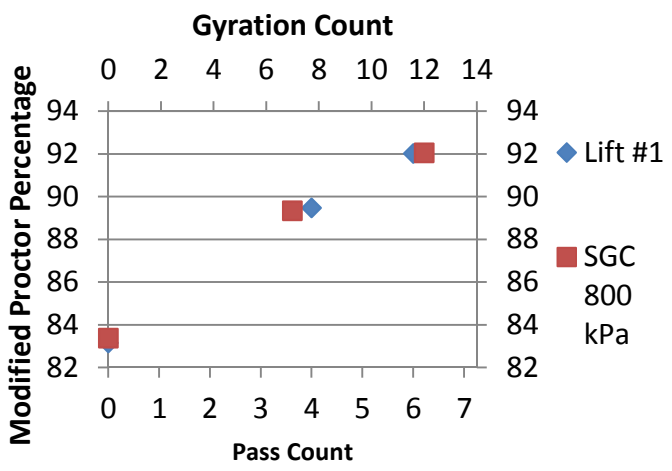
Development of Energy Based Method – DGA Energy Predictions

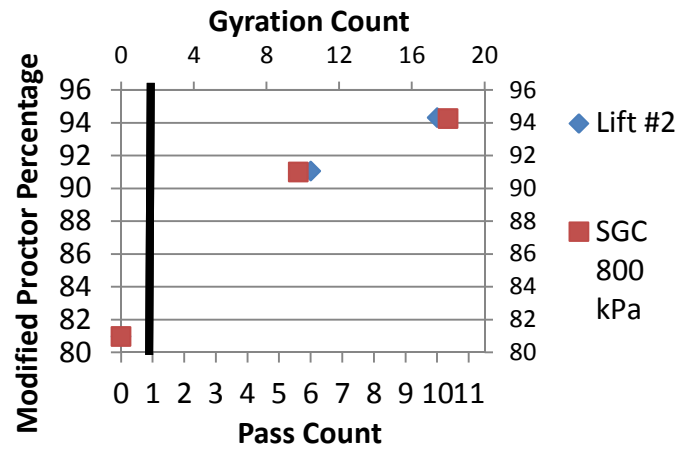


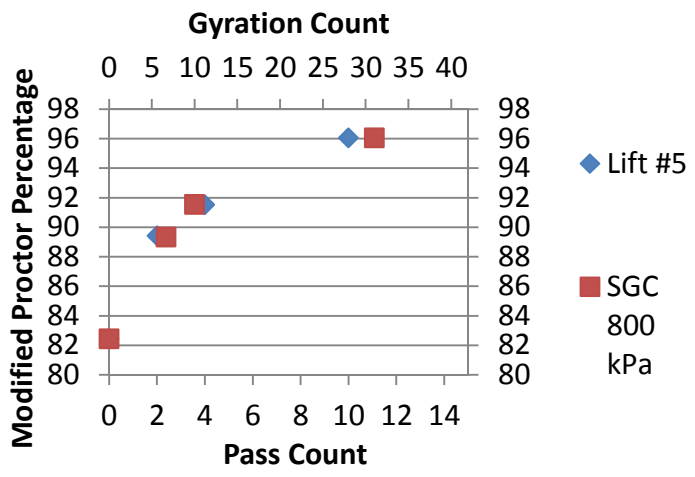
Where $\alpha = 0.80762$ and $\beta = 0.7081$

Rowan University

P-154 Correlation Between SGC and Construction Event Number







Rowan University

Lab to Field Correlations

N roller	E	N lab	Dry Density (% Modified Proctor)	Moisture Content (%)
Z1	Y1	X1	80	%
Z2	Y2	X2	85	%
Z3	Y3	X3	90	%
Z4	Y4	X4	95	%
Z5	Y5	X5	100	%

Rowan University

Field Energy Estimation

$$\mathbf{E} = \frac{\mathbf{fWP}}{\mathbf{Bt}} \qquad \text{(Selig, 1971)}$$

E=Compactive Effort per unit volume (ft-lb/ft3)
f=Coefficient of Compaction
P=Number of passes
B=Roller Width (ft)
t=Compacted lift thickness (ft)
W=Total weight (lb)

Rowan University

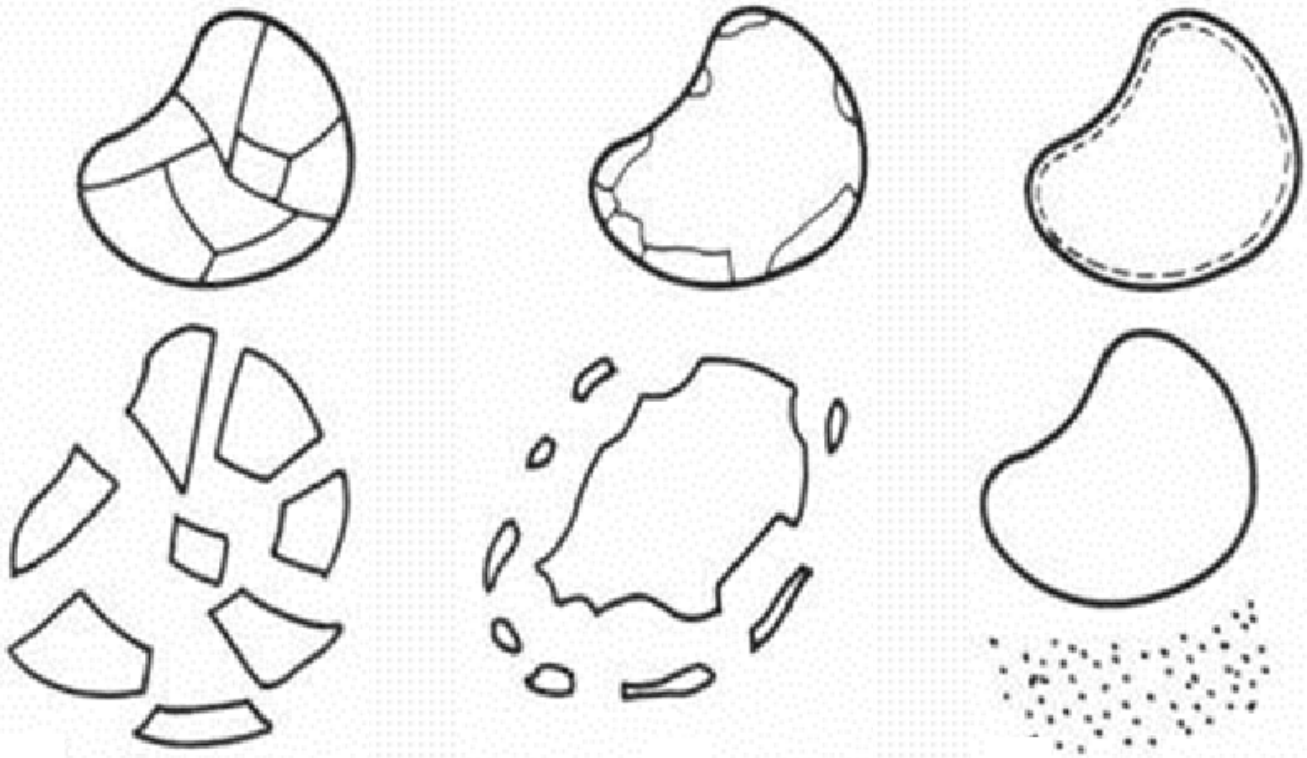
Lab to Field Correlations

Material P-154
Modified Maximum DD 128.3 pcf

Compaction Percent	DD_{Target} (pcf)	MC %	N	E (in-lb/in^3)	# Passes (Pneumatic)
140%	179.62	2	2.94E+11	5.3422E+11	14317113054
		3	1.17E+11	1.7147E+11	4595396708
		4	4.57E+10	55443948829	1485900371
130%	166.79	2	2.39E+09	4336082533	116207211
		3	9.55E+08	1397172220	37444280
		4	3.69E+08	447601879.5	11995751
120%	153.96	2	1.93E+07	34984145.93	937577
		3	7813583	11434004.48	306432
		4	2969388	3605335.417	96623
110%	141.13	2	149918	272034.6239	7291
		3	64590	94517.90553	2533
		4	23692	28766.2027	771
100%	128.3	2	740	1342.369109	36
		3	526	770.2270944	21
		4	171	207.7042096	6
95%	121.885	2	24	43.99480427	1
		3	24	35.38540406	1
		4	21	25.71439882	1
90%	115.47	2	4	7.103764294	1
		3	3	4.599758023	1
		4	2	2.056142058	1

Rowan University

Crushing Mechanism Leading to Excessive Compaction



Fracture Attrition Abrasion

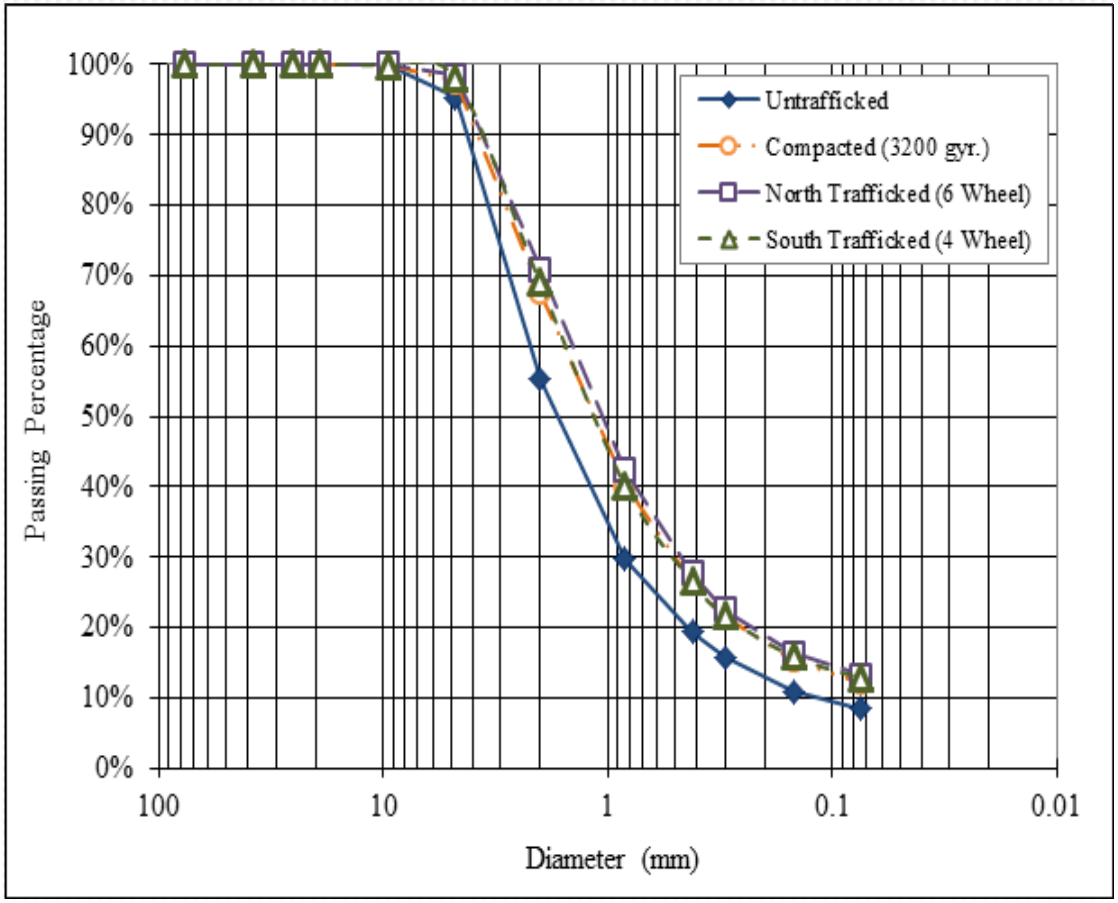
(Ramamurthy et al., 1974)

Rowan University

Hypothesis of Mechanism of Compaction

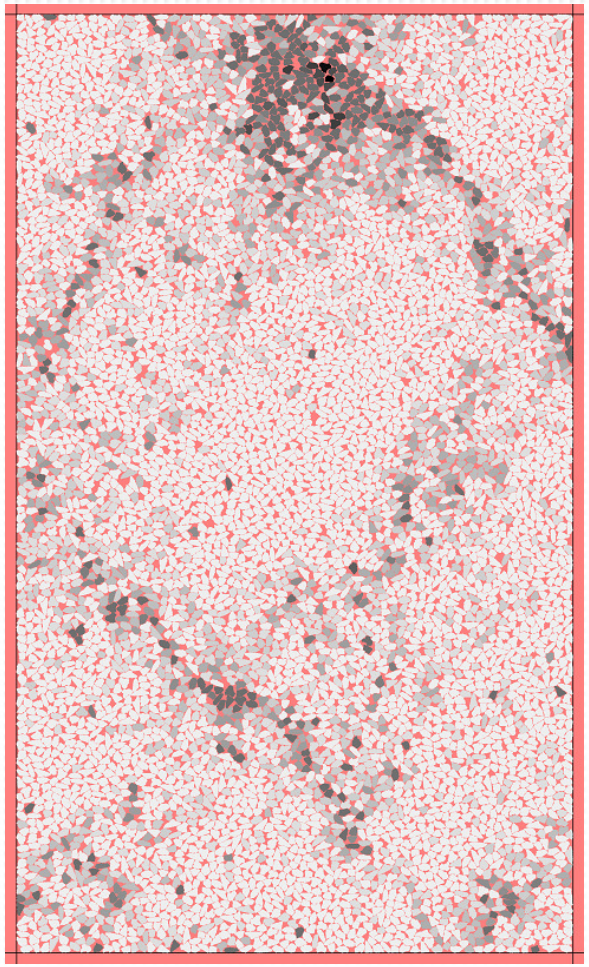
Aggregate is undergoing more abrasion and attrition

- Less angular aggregate as trafficking progresses.
- Higher compaction due to reduced interlock.
- Results in weaker samples.

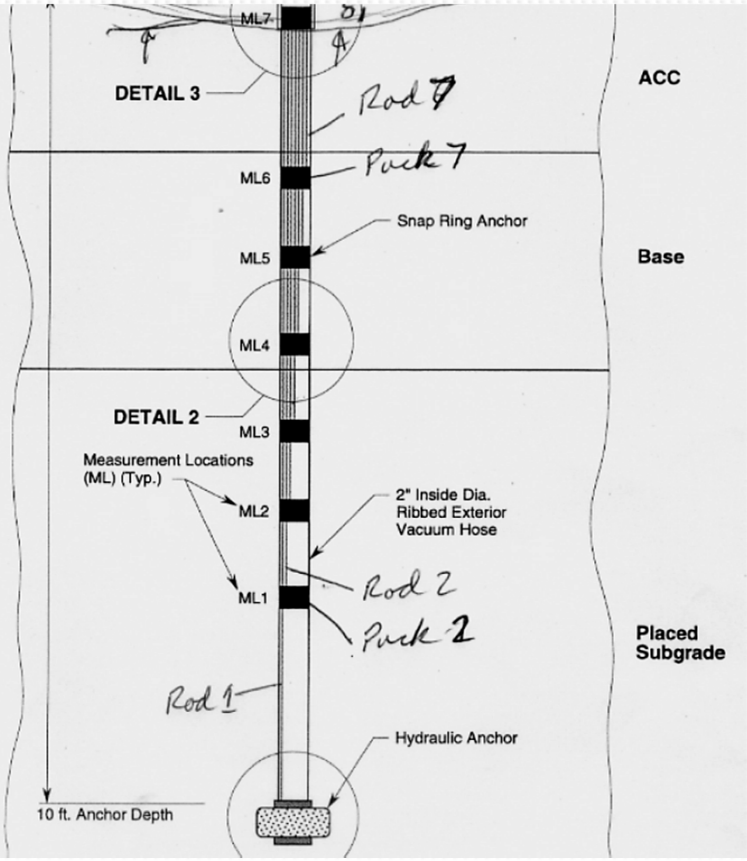


Rowan University

Hypothesis of Influence of Sample Height (thickness of subbase layer)

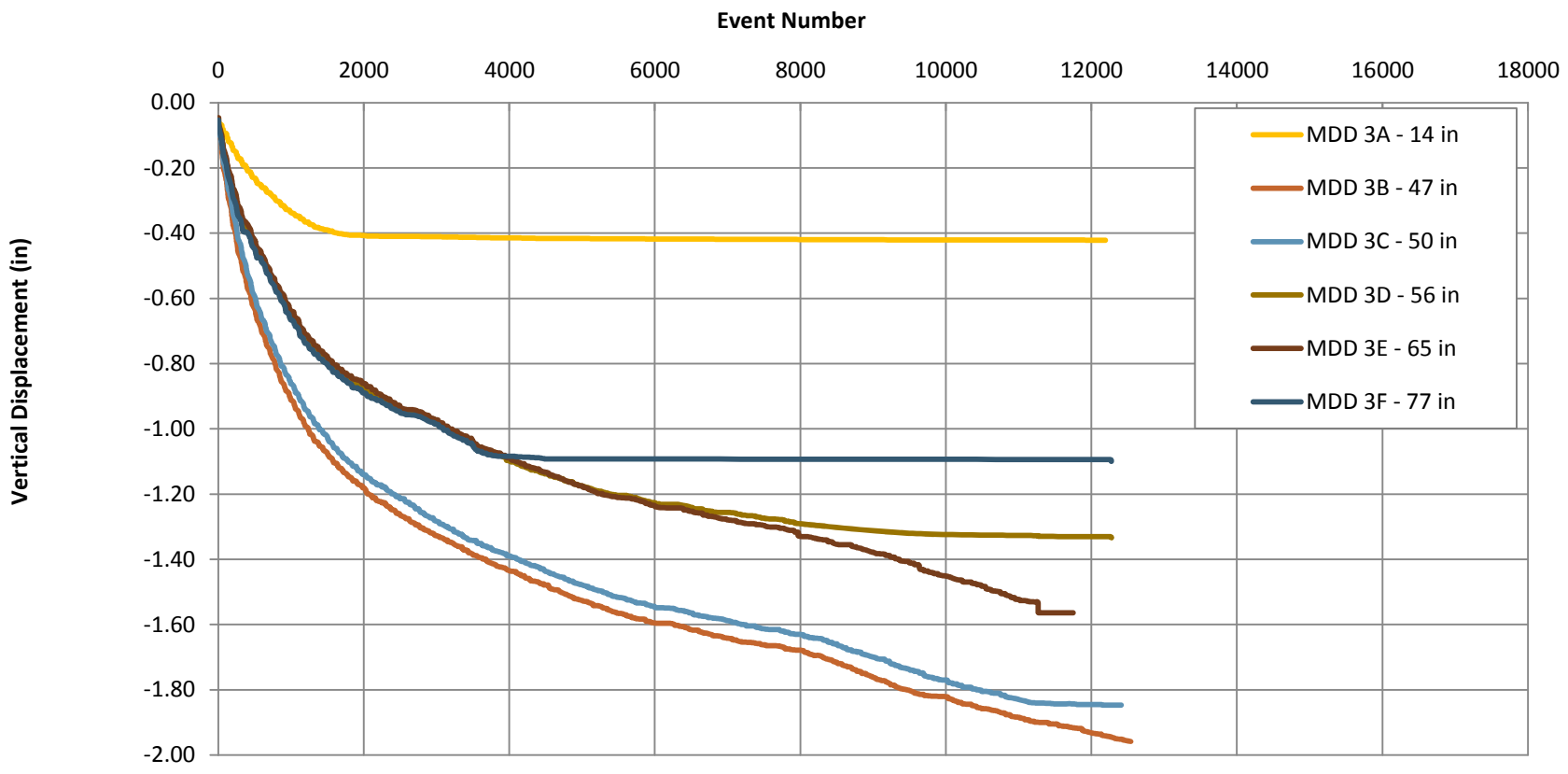


Multi Depth Deflectometer (MDD)



Rowan University

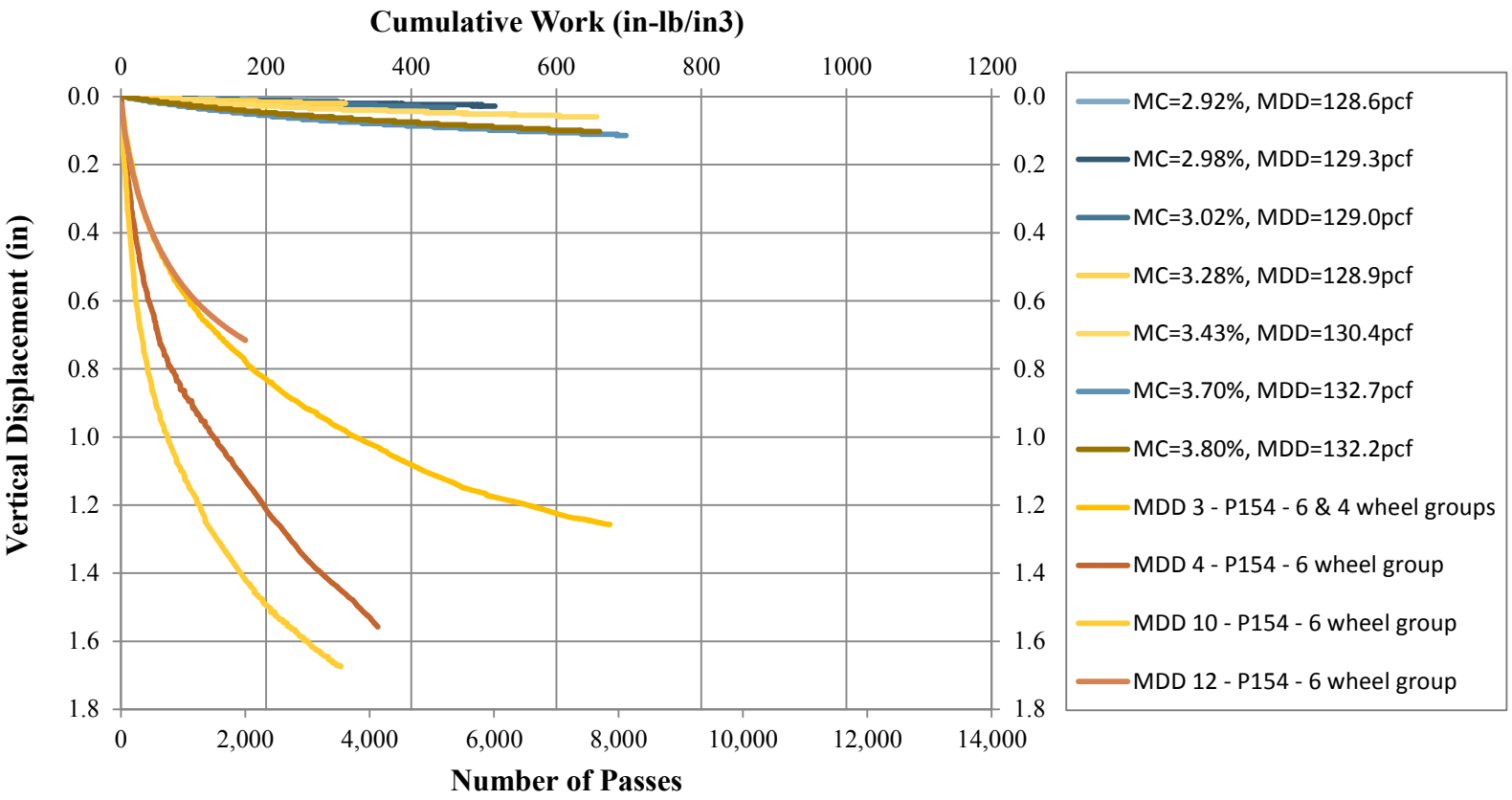
Field Trafficking Data Issues



Displacement Wanted is MDD #A – MDD #B to Obtain Subbase Displacement

Rowan University

Comparison of field and lab data during trafficking



Rowan University

SGC vs. Proctor Conclusions

- SGC is capable of replicating field compaction results
  - Higher densities than Modified Proctor test with similar trend
  - Construction densities achieved at low gyration counts
- Compaction Mechanism for Trafficking
  - Attrition and abrasion reduces angularity and interlock

Rowan University

Lab vs. Field Conclusions

- Empirical relationship between passes of the roller and gyrations of SGC was developed
- Relationships were developed to predict the number of gyrations required to achieve a certain moisture-density condition for P154 and DGA materials. Relationships between gyration count and cumulative work were also presented
- SGC cannot replicate field results during trafficking
- A method to estimate roller compaction energy is being implemented.

Rowan University

Future Work

- Finish analysis of P-209 testing data
- Implementation of a method to estimate roller compaction energy in the field
- Establish a standard procedure for SGC compaction to replace the proctor method
- Determine compaction factor "*f*" from field compaction testing

Rowan University

Acknowledgments

- FAA Airport Technology Research and Development Branch AJP-6310
- The contents of the presentation reflect the views of the authors, who are responsible for the facts and accuracy of the data presented within. The contents do not necessarily reflect the official views and policies of the FAA. The presentation does not constitute a standard, specification, or regulation.

Rowan University

Questions?

Rowan University