IOWA STATE UNIVERSITY | WISCONSIN UNIVERSITY OF WISCONSIN–MADISON | MICHIGAN STATE UNIVERSITY

# Determining Pavement Design Criteria for Recycled Aggregate Base and Large Stone Subbase


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**MnDOT Project TPF-5(341)**

Monthly Meeting

April 2, 2020

# AGENCY MEMBERS

- MnDOT
- Caltrans
- MDOT
- IDOT
- LRRB
- MoDOT
- WisDOT
- NDDOT
- Iowa DOT
- Illinois Tollway

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- Aggregate & Ready Mix of MN
- Asphalt Pavement Alliance (APA)
- Braun Intertec
- Infrasense
- Diamond Surface Inc.
- Flint Hills Resources
- International Grooving & Grinding Association (IGGA)
- Midstate Reclamation & Trucking
- MN Asphalt Pavement Association
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- National Concrete Pavement Technology Center
- Roadscanners
- University of Minnesota - Duluth
- University of New Hampshire
- Mathy Construction Company
- Michigan Tech Transportation Institute (MTTI)
- University of Minnesota
- National Center for Asphalt Technology (NCAT) at Auburn University
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- Helix Steel
- Ingios Geotechnics
- WSB
- Cargill
- PITT Swanson Engineering
- University of California Pavement Research Center
- Collaborative Aggregates LLC
- American Engineering Testing, Inc.
- Center for Transportation Infrastructure Systems (CTIS)
- Asphalt Recycling & Reclaiming Association (ARRA)
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- BASF Corporation
- Upper Great Plains Transportation Institute at North Dakota State University
- 3M
- Pavia Systems, Inc.
- All States Materials Group
- Payne & Dolan, Inc.
- Caterpillar
- The Dow Chemical Company
- The Transtec Group
- Testquip LLC
- Hardrives, Inc.
- Husky Energy
- Asphalt Materials & Pavements Program (AMPP)
- Concrete Paving Association of MN (CPAM)
- MOBA Mobile Automation
- Geophysical Survey Systems
- Leica Geosystems
- University of St. Thomas
- Trimble

# OUTLINE

- Follow-up
- Test cells & materials
- Task 7

# FOLLOW-UP

- **Task 1** – Literature review and recommendations
- **Task 2** – Tech transfer "state of practice"
- **Task 3** – Construction monitoring and reporting
- **Task 4** – Laboratory testing
- **Task 5** – Performance monitoring and reporting
- **Task 6** – Instrumentation
- **Task 7** – Pavement design criteria
- **Task 8 & 9** – Draft/final report

Green – Completed
Red – In Progress

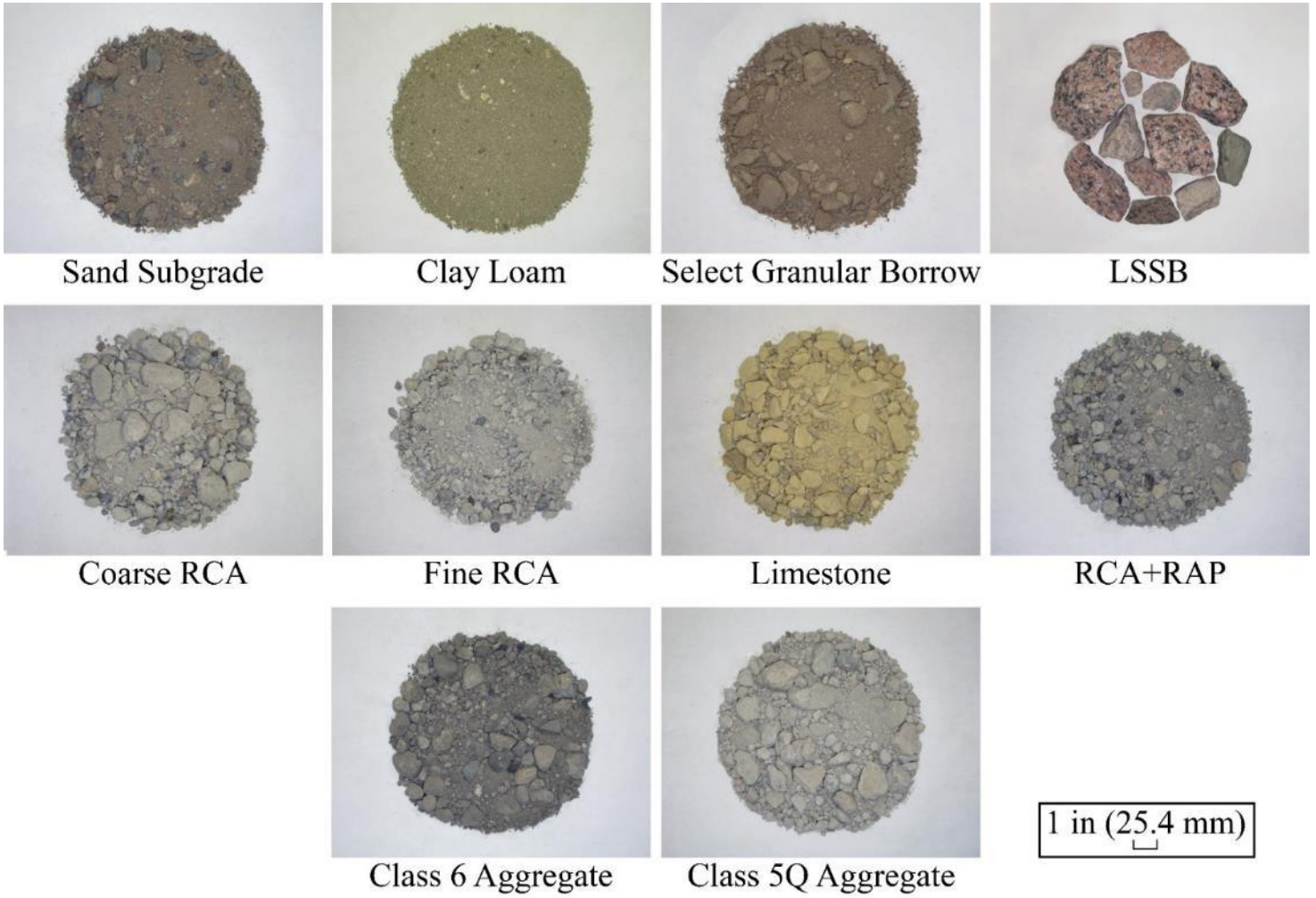
# TEST CELLS

| Recycled Aggregate Base | | | | Large Stone Subbase | | Large Stone Subbase with Geosynthetics | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 185 | 186 | 188 | 189 | 127 | 227 | 328 | 428 | 528 | 628 | 728 |
| 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave | 3.5 in Superpave |
| 12 in Coarse RCA | 12 in Fine RCA | 12 in Limestone | 12 in RCA+RAP | 6 in Class 6 Aggregate | 6 in Class 6 Aggregate | 6 in Class 5Q Aggregate | 6 in Class 5Q Aggregate | 6 in Class 5Q Aggregate | 6 in Class 5Q Aggregate | 6 in Class 5Q Aggregate |
| 3.5 in S. Granular Borrow | 3.5 in S. Granular Borrow | 3.5 in S. Granular Borrow | 3.5 in S. Granular Borrow | 18 in LSSB (1 lift) | 18 in LSSB (1 lift) | 9 in LSSB TX | 9 in LSSB TX+GT | 9 in LSSB BX+GT | 9 in LSSB BX | 9 in LSSB |
| Sand | Sand | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam | Clay Loam |

S. Granular Borrow = Select Granular Borrow

TX = Triaxial Geogrid
BX = Biaxial Geogrid
GT = Nonwoven Geotextile

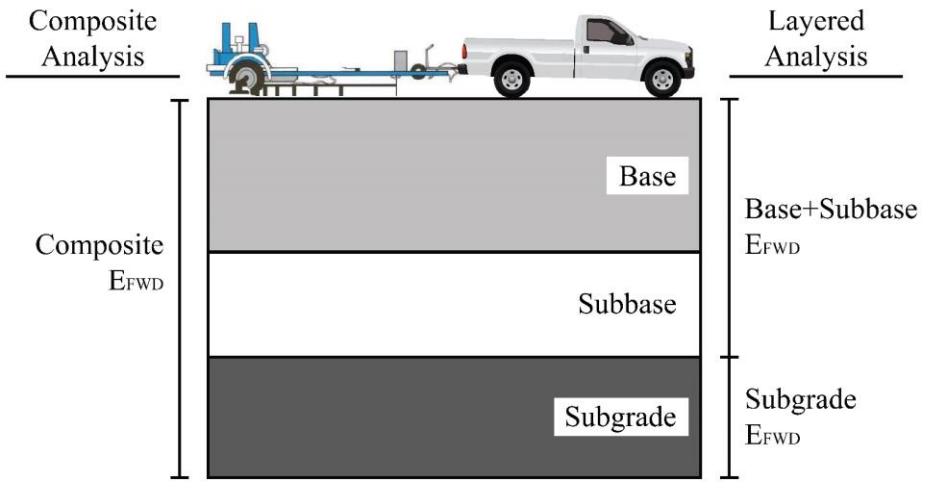
# MATERIALS


Sand Subgrade
Clay Loam
Select Granular Borrow
LSSB
Coarse RCA
Fine RCA
Limestone
RCA+RAP
Class 6 Aggregate
Class 5Q Aggregate
1 in (25.4 mm)

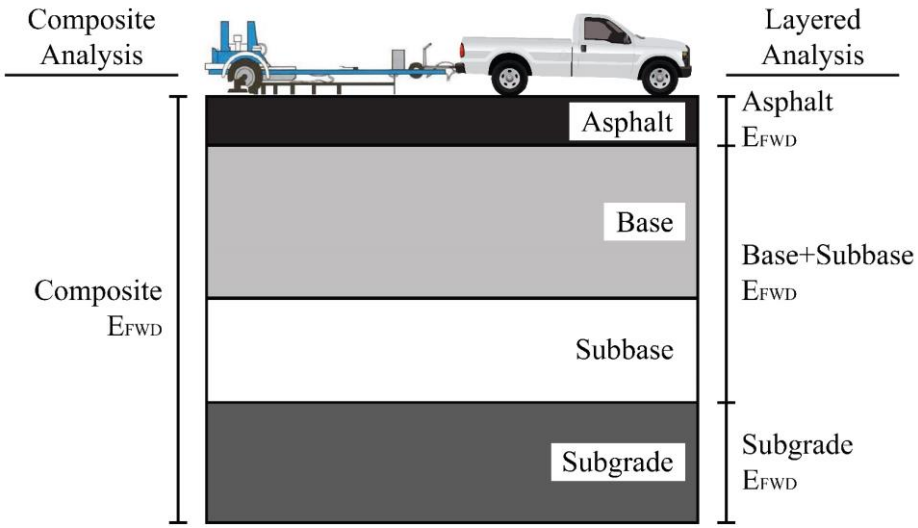
# TASK 7

## Outline

- Compare preliminary (during construction) and long-term performance (after construction)
  - Falling weight deflectometer (FWD)
  - Rutting




During construction




After construction

# TASK 7

## Outline

- Summarize field and laboratory test results and establish correlations between laboratory and field test results

### Laboratory Tests

**Index properties**
- Classification of the materials
- Specific gravity ($G_s$) and absorption
- Proctor compaction
- Asphalt binder & residual mortar contents
- Water repellency

**Saturated and unsaturated properties**
- Permeability ($K_{sat}$)
- Soil water characteristic curve (SWCC)

**Stereophotography**
- Particle size & shape analysis

**Gyratory compaction and abrasion**
- Abrasion on the particle size & shape

### Field Tests

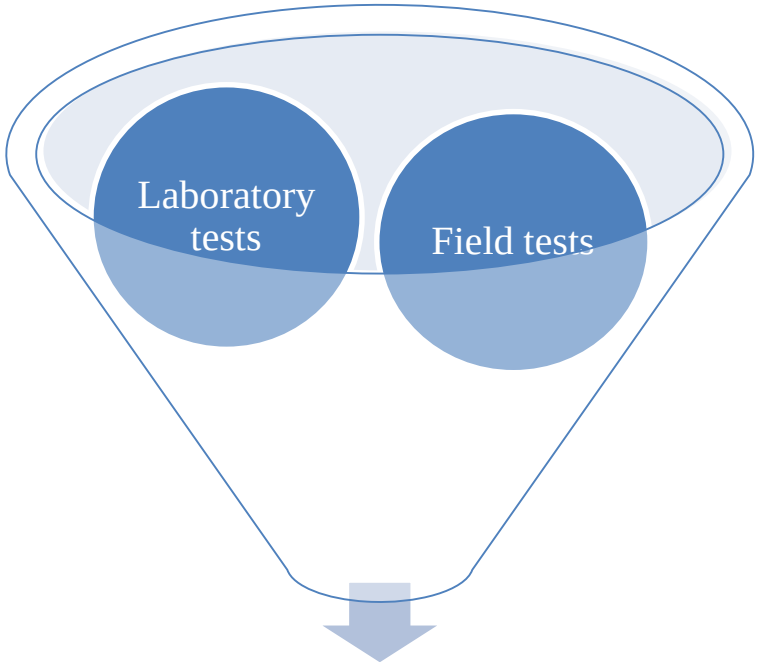
**During construction**
- Nuclear density gauge
- Dynamic cone penetrometer (DCP)
- Lightweight deflectometer (LWD)
- Gas permeameter (GPT) test
- Intelligent compaction (IC)
- Falling weight deflectometer (FWD)

**After construction**
- Falling weight deflectometer (FWD)
- Frost heave & thaw settlement
- Rutting
- International roughness index (IRI)
- Pavement distresses

# TASK 7

## Outline

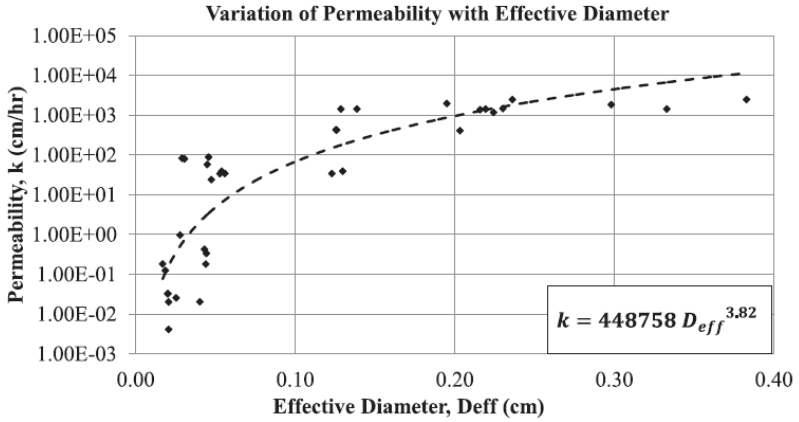
- Develop methods to estimate stiffness and hydraulic properties

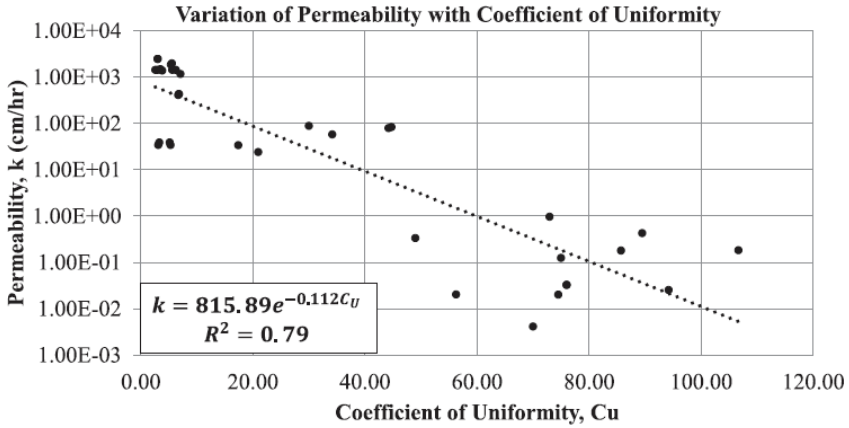


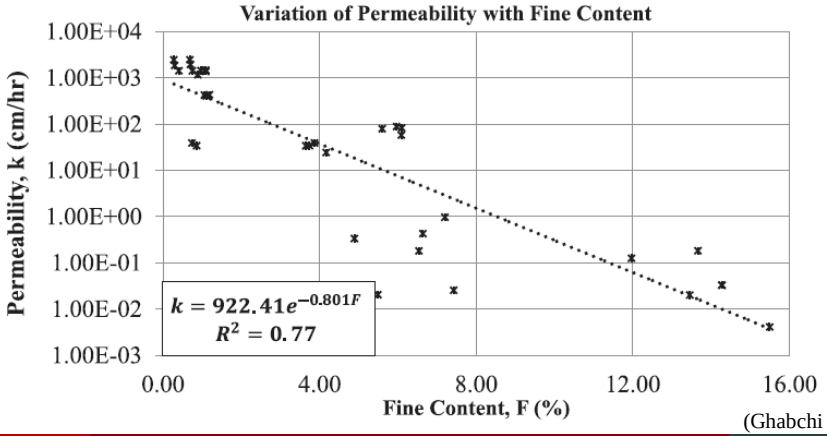
# TASK 7

## Outline

- Permeability vs. gradation



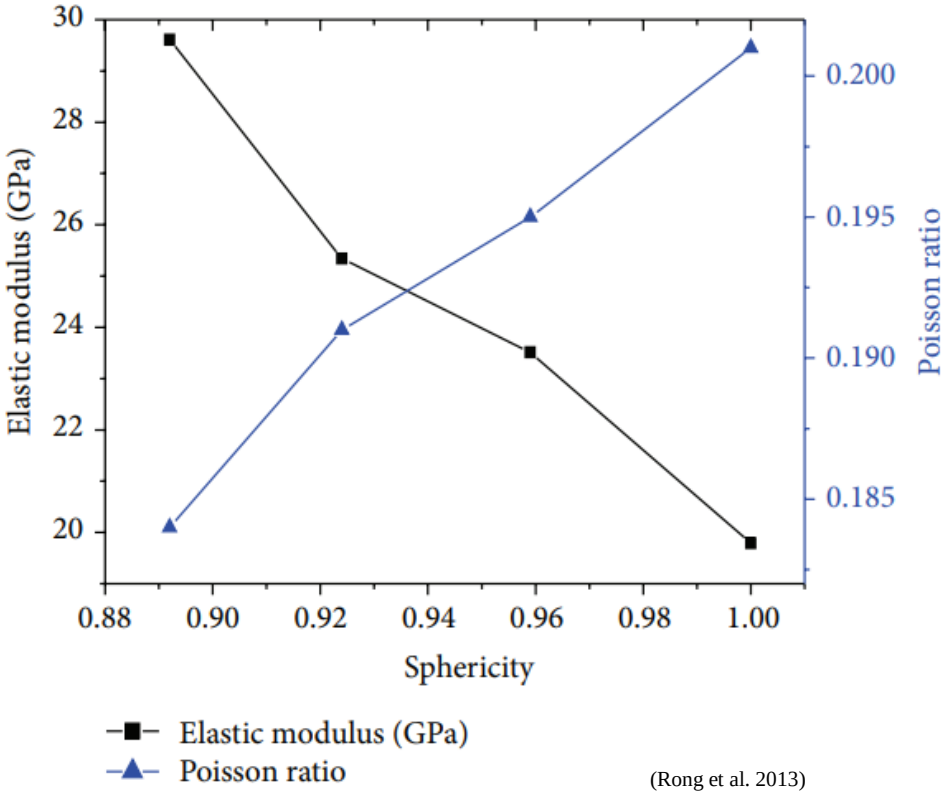




(Ghabchi et al. 2015)

# TASK 7

## Outline

- Stiffness vs. particle shape

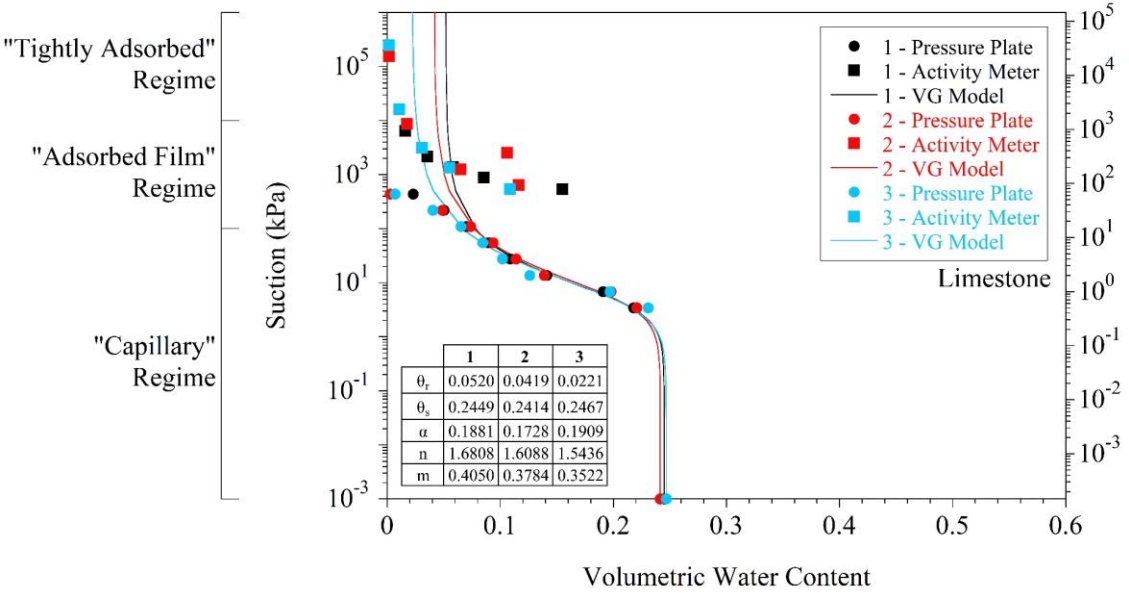


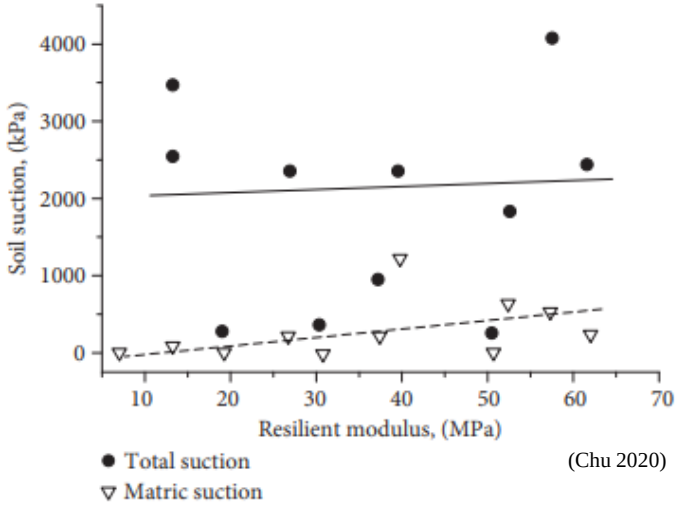

(Rong et al. 2013)

# TASK 7

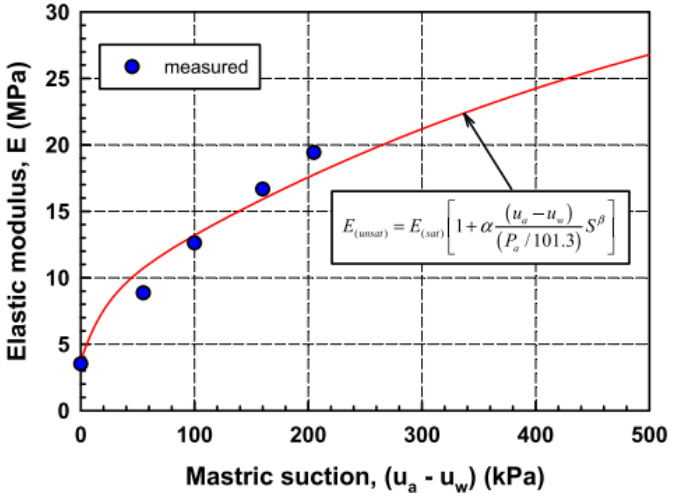
## Outline

- Suction vs. stiffness
  - Base and subgrade materials




(Chu 2020)




(Oh and Vanapalli 2018)

# TASK 7

## Outline

| Materials | Compaction Characteristics | Correlation Equations | $R^2$ |
|---|---|---|---|
| RCA | $W_{opt}$ (%) | -0.064 *$Cu$ + 0.763 *$Absorption(\%)$ + 7.75 | 0.65 |
| | $\gamma_{dmax}$ (kN/m$^3$) | -0.374 *$W_{opt}(\%)$ + 23.6 | 0.83 |
| RAP | $W_{opt}$ (%) | -0.0626 *$Cu$ - 1.349 *$Absorption(\%)$ + 9.84 | 0.92 |
| | $\gamma_{dmax}$ (kN/m$^3$) | -0.289* $W_{opt}$ $(\%)$ + 22.42 | 0.83 |

(Edil et al. 2012)

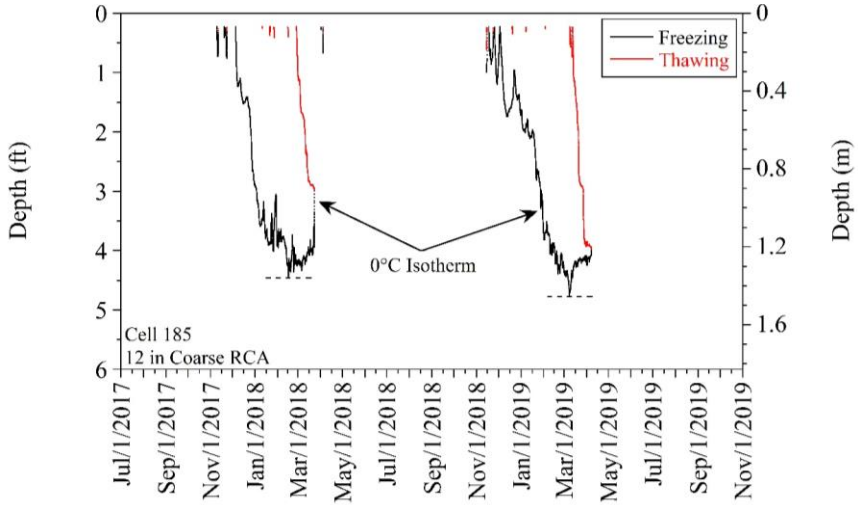
| Materials | Summary Resilient Modulus (SRM) (Mpa) | Correlation Equations | $R^2$ |
|---|---|---|---|
| RCA | $SMR_{EXT}$ | 171.646-(3.482*$D_{30}$) + (22.378*Impurities %) | 0.89 |
| | $SMR_{INT}$ | 14683.478 - (36.764*$D_{30}$) - (72.719*Wopt) | 0.89 |
| RAP | $SMR_{EXT}$ | (117.493 * $D_{30}$) + (19.472 *$\gamma_{dmax}$ + (27.128 * Asphalt Content(%)) - (18.510 * Absorption(%)) -427.329 | 0.99 |
| | $SMR_{INT}$ | (-2268.783)-(285.884*Fines %)+(628.742*Asphalt content (%))+ (201.107*$D_{60}$)-(483.158*$G_s$)-(58.243*Absorption (%)) | 0.99 |

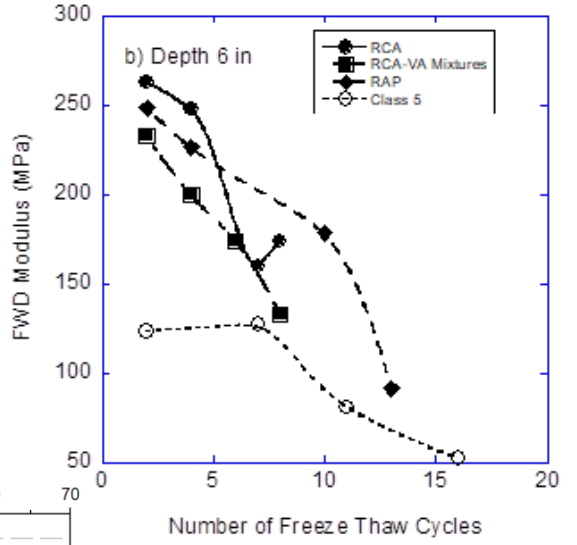
(Edil et al. 2012)

# TASK 7

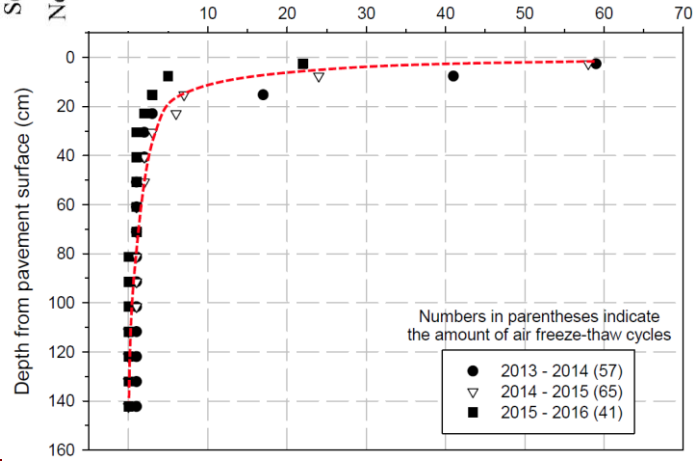
## Outline

- Analyze the effects of frost depth & number of F-T cycles




(Edil et al. 2017)




(Zhang 2016)

# TASK 7

## Outline

- Recommend construction specifications
  - Gradation of RCA
    - Residual mortar content
    - Unhydrated cement content
    - Absorption and hydrophilicity
    - Abrasion
    - Degree of compaction
    - Drainage properties
  - Asphalt content & hydrophobicity
  - Stress-hardening & stress-softening behaviors
  - Stresses at layer interfaces (asphalt/base & base+subbase/subgrade)
  - Thermal properties & frost penetration depth
  - Effects of geosynthetics

# TASK 7

**Outline**

- AASHTOWare Pavement ME Design
  - Different thicknesses
  - Different subgrade layers (sand & clay loam)
- Recommend pavement design input values for each NRRA state per their pavement design methods

Thank You!

**QUESTIONS??**

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