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

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MnDOT Project TPF-5(341)
Kick of Meeting
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RESEARCH TEAM

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➢ Co-Principal Investigator – Ashley Buss
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➢ Co-Principal Investigator – William Likos
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  ➢ Professor Emeritus – Department of Civil and Environmental Engineering
NRRA Members (Agency Partners)

- MnDOT
- Caltrans
- MDOT
- Illinois DOT
- LRRB
- MoDOT
- WiscDOT
NRRA Members (Industry Partners)

- Aggregate and Ready Mix (Association of MN)
- APA
- Braun Intertec
- CPAM
- Diamond Surface Inc
- Flint Hills Resources
- IGGA
- MIDSTATE (Reclamation and Trucking)
- MN Asphalt Pavement Association
- Minnesota State University
- NCP Tech Center
- Road Scanners
- University of Minnesota-Duluth
- University of New Hampshire
- MATHY
- 3M
- Paviasystems
- Michigan Tech
- University of Minnesota
- NCAT
- GSE Environmental
- HELIX
- Ingios
- WSB
- Cargill
- PITT Swanson Engineering
- INFRASENSE
- Collaborative Aggregates LLC
- American Engineering Testing, Inc.
- CTIS
- ARRA
- 1st
- O-BASF
- North Dakota State University
- All States Materials Group
PROBLEM STATEMENT

Annual Aggregate Production x 10^6

Years

0 200 400 600 800 1000 1200 1400 1600

2006 2011

$
PROBLEM STATEMENT

Where aggregate is in limited occurrence
PROBLEM STATEMENT
PROBLEM STATEMENT
PROBLEM STATEMENT

- 2 billion tons/year aggregate produced (FWHA 2004)
- 200 million tons/year of RCA and 90 million tons/year of RAP generated (FHWA 2011)

http://www.gratechcompanyltd.com/aggregate.htm
PROBLEM STATEMENT

Annual Quantity Used

From Edil et al. (2012)
Limited information about the performance of RCA and RAP built on LSSB.
- Different mixtures of RCA-RAP
- Freeze-thaw durability
- Frost heave-thaw weakening settlement
- Stiffness

No pavement design guideline for pavements built with RCA, RAP on LSSB.

Verify available methods to predict stiffness and strength of these materials with simple index properties.
OBJECTIVES

1st Goal – Determine the field and laboratory performance
- FWD, LWD, DCP, Intelligent compaction (IC) data
- Unsaturated characteristics, index properties

2nd Goal – Develop a method to estimate the stiffness and permeability
- Percent crushing of recycled aggregates and LSSB
- Sphericity, angularity, and surface texture of aggregates
- Gravel, sand, fines content, gravel-to-sand ratio, D_{10}, D_{30}, D_{50}, D_{60}

3rd Goal – Prepare a pavement design and construction specification
- Performance
- Cost benefits
- Life cycle cost
Overview of Research Plan

- 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 and Climatic Effects
- Task 6 – Instrumentation
- Task 7 – Pavement Design Criteria
- Task 8&9 – Draft/Final Report
Task 1

Task 1 – Literature Review and Recommendations

Conduct a comprehensive literature review on:

- Current recycling practices of State DOTs from different climatic regions
- Previous laboratory and field investigations on the use of RCA, RAP, and LSSB
- In depth review on a recently published FHWA report (Edil 2012)
Task 2

Task 2 – Tech Transfer “State of Practice”

Prepare a report:

- To guide local county engineers and state DOTs on how to apply recommended methods and designs to built highway pavement foundation systems with recycled materials and LSSB.

- Specific information will be provided about the mixtures of RCA-RAP-VA, RCA-VA, and LSSB built with different thickness and geosynthetics.

- CP Tech Center will assist to the research team
# Task 3

## Task 3 – Construction Monitoring and Reporting

<table>
<thead>
<tr>
<th>South Side Cells (West to East)</th>
<th>Recycled Unbound Base</th>
<th>Large Subbase</th>
<th>Large Subbase and Geogrid Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>185</td>
<td>186 87</td>
<td>188 189</td>
<td>127 227 328 428 528 628 728</td>
</tr>
<tr>
<td>3.5&quot; HMA</td>
<td>3.5&quot; HMA</td>
<td>3.5&quot; HMA</td>
<td>3.5&quot; HMA 3.5&quot; HMA 6&quot; HMA</td>
</tr>
<tr>
<td>12&quot; Coarse RCA</td>
<td>4&quot; HMA 12&quot; Recycled Aggregate Base Class 6</td>
<td>6&quot; Class 6 6&quot; Class 6</td>
<td>6&quot; Class 5Q 6&quot; Class 5Q 6&quot; Class 5Q 6&quot; Class 5Q</td>
</tr>
<tr>
<td>3.5&quot; Select Granular Borrow</td>
<td>3.5&quot; Select Granular Borrow</td>
<td>18&quot; Large Subbase 1 Lift 18&quot; Large Subbase 2 Lift</td>
<td>9&quot; Large Subbase Grid 1 9&quot; Large Subbase Fabric Grid 1 9&quot; Large Subbase Fabric Grid 2 9&quot; Large Subbase Grid 2</td>
</tr>
<tr>
<td>Sand</td>
<td>Clay</td>
<td>Clay</td>
<td>Clay</td>
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</tbody>
</table>

Iowa State University

University of Wisconsin-Madison
Task 4

Task 4 – Laboratory Testing

MnDOT
- Compaction
- Atterberg
- Moisture
- Gradation
- Abrasion

ISU
- Image Analyses
- GAIA

UW-Madison
- Unsaturated Geomaterial Behavior
  - Water retention curve
  - Permeability

ISU
- Statistical Analyses
  - Estimation of $M_R$ from common tests
Task 4

Task 4 – Example of Freeze-Thaw Behavior of Recycled Materials

*Normalized resilient modulus of recycled concrete aggregate and recycled asphalt pavement at 5-10 F-T cycles (a) vs $D_{30}$, (b) vs G/S ratio (from Rosa et al. 2017).*
Task 5 & 6

Task 5 & 6 – Performance Monitoring and Reporting, and Climatic Effects

Analyze the following data that will be collecting throughout the project

- FWD, frost heave-thaw settlement, IRI, rutting, surface survey.
- Temperature, moisture, matric suction, strain.
  - Determine freeze-thaw cycle numbers and its impact on pavement performance
  - Determine impact of frost heave and thaw settlements on pavement performance
  - Predict frost/thaw depth
Task 5 & 6

Task 5 & 6 – FWD variation over long period of time

FWD elastic modulus of RCA base layer during 7 years (Data collected from MnDOT 2008 project).
Task 5 & 6 – FWD variation with freeze-thaw cycles

- **a)** Cumulative number of F-T cycles since 2008 in RCA base layer and **b)** field elastic modulus of RCA, RCA-VA blend, RAP, and Class 5 aggregate field test sections with F-T cycles (Edil et al. 2017).
Task 5 & 6 – Frost depth prediction over the years

Li et al. (2016)
Task 7 – Determine Pavement Design Criteria

Prepare a report that:

- Summarizes the findings from the laboratory and field tests
- Provides detailed review on pavement design inputs in terms of benefits and costs
- Analyzes the cost effectiveness of using recycled materials and LSSB
- Shows correlations between the index properties and stiffness/permeability of geomaterials tested
- Provides the results of sustainability assessment analyses
Task 8&9

Task 8&9 – Draft/Final Report
## Schedule

| TASKS   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
|---------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Task 1  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 2  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 3  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 4  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 5  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 6  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 7  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 8  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Task 9  |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
PRODUCTS & DELIVERABLES

- Quarterly progress reports as required
- Draft final report
- Final report
- Technology transfer brief
- A copy of the executive final presentation
AGENCY ASSISTANCE

- Access to data collected during construction
- Access to data being collected throughout the project
- Assistance with installation of matric suction sensors
Thank You!

QUESTIONS??