IOWA STATE UNIVERSITY
Dept. of Civil, Construction & Envr. Engineering
WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON
Dept. of Civil & Envr. Engineering

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

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MnDOT Project TPF-5(341)
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RESEARCH TEAM

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NRRA Members (Agency Partners)

- MnDOT
- Caltrans
- MDOT
- Illinois DOT
- LRRB
- MoDOT
- WisDOT

NRRA Members (Industry Partners)

- Aggregate and Ready Mix
  (Association of MN)
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- 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
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- Cargill
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- American Engineering Testing, Inc.
- CTIS
- ARRA
- 1st
- O-BASF
- North Dakota State University
- All States Materials Group

OUTLINE

- **Pavement Systems and Base/Subbase Course Applications**
  - Pavement Systems
  - Recycled Materials in Base Course Applications
  - Large-Size Aggregates in Subbase Course Applications
  - Motivation and Purpose of This Research
- **Engineering Properties of RAP, RCA and LSSB Materials**
  - Gradation Characteristics
  - Compaction Characteristics
  - Hydraulic Properties
  - Strength Properties
  - ✓ Shear Strength Properties
  - ✓ Stiffness Properties
  - ✓ Permanent Deformation Properties
  - ✓ Creep Properties
  - ✓ Freeze-Thaw and Wet-Dry Durability
- **Environmental Properties of RAP and RCA**
  - Properties of RAP
    - pH Characteristics
    - Heavy Metal Leaching Characteristics
    - Poly-Aromatic Hydrocarbons (PAHs) Leaching Characteristics
  - Properties of RCA
    - pH Characteristics
    - Heavy Metal Leaching Characteristics
- **Geosynthetic Applications**
  - Functions of Geosynthetics
  - Effects of Using Geosynthetics
- **Design Methods**
- **Selected Practices of State DOTs**
- **Recommendations**
- **References**

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Gradation Characteristics

- Gradation of RAP & RCA (Cosentino and Kalajian 2001)
  - Original aggregate type
  - Milling operations
  - Crushing methods
- MnDOT (LRRB 2016)
  - RAP – as class 7
  - RCA – as class 5
- Angularity – RCA > RAP
- Large-size aggregates (Kazmee et al. 2016)
  - Image analysis
  - Low angularity – single crushing

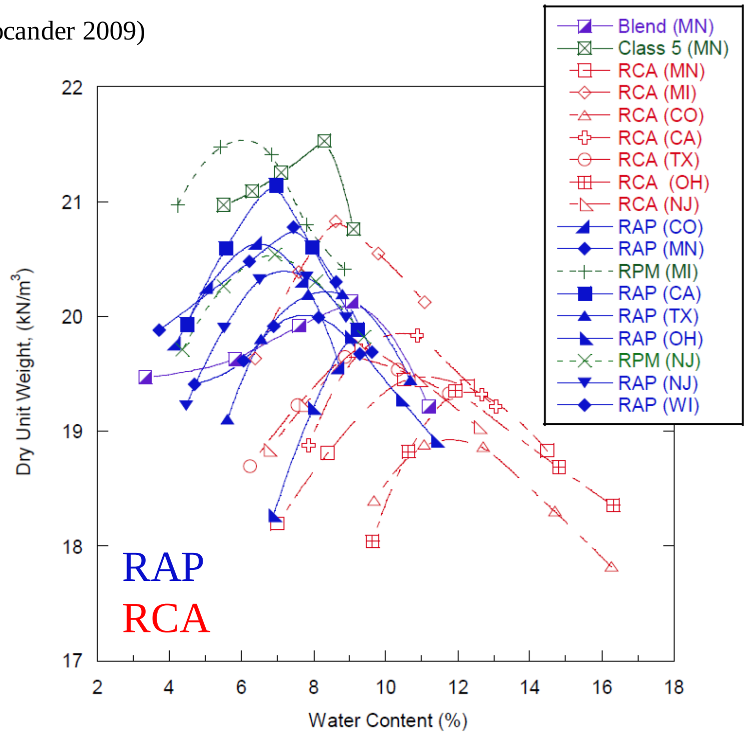
Fine- to coarse-grained aggregates (from left to right)
(http://engineeringfeed.com/8-factors-affect-workability-fresh-concrete)

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Compaction Characteristics

- RAP ➔ lower γ_{dmax} & lower OMC
  - Asphalt & low fines content (Guthrie et al. 2007, Locander 2009)
  - Hydrophobicity (Rahardjo et al. 2010)
- RCA ➔ lower γ_{dmax} & higher OMC
  - Cementation (Chen and Brown 2012; Hussain and Dash 2010)
  - Hydrophilicity (Rahardjo et al. 2010)



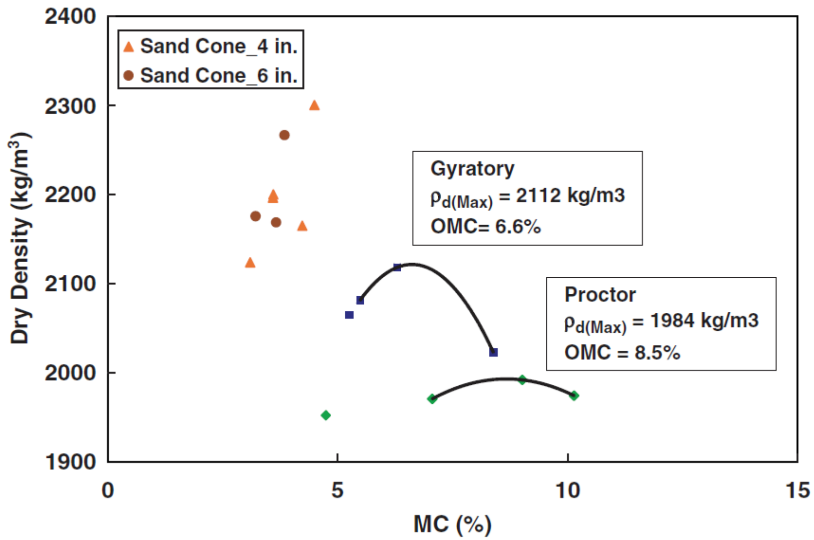
Compaction characteristics of recycled and virgin aggregates (Edil et al. 2012)

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Compaction Characteristics

- Gyratory compactor ➔ better simulate in-situ (Kim et al. 2007)



Difference between Proctor and gyratory compaction methods (Kim et al. 2007)

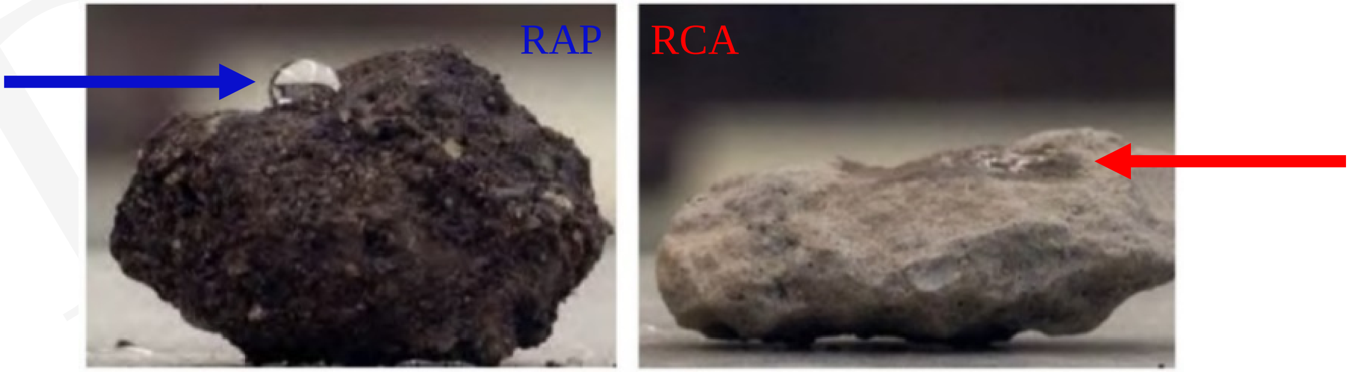
- Temperature ↑ from 21°C (70°F) to 49°C (120°F) (Montemayor 1998)
  - Binding quality ↑
  - About 3.5% increase in γ_{dmax}

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Hydraulic Properties

- Surface characteristics (Edil et al. 2012; Rahardjo et al. 2010)
  - RAP - hydrophobic
  - RCA - hydrophilic
- Contact angle ↑, water repellency ↑ (Letey et al. 2000; Edil et al. 2012)
  - RAP > 90°
  - RCA ~ 0°



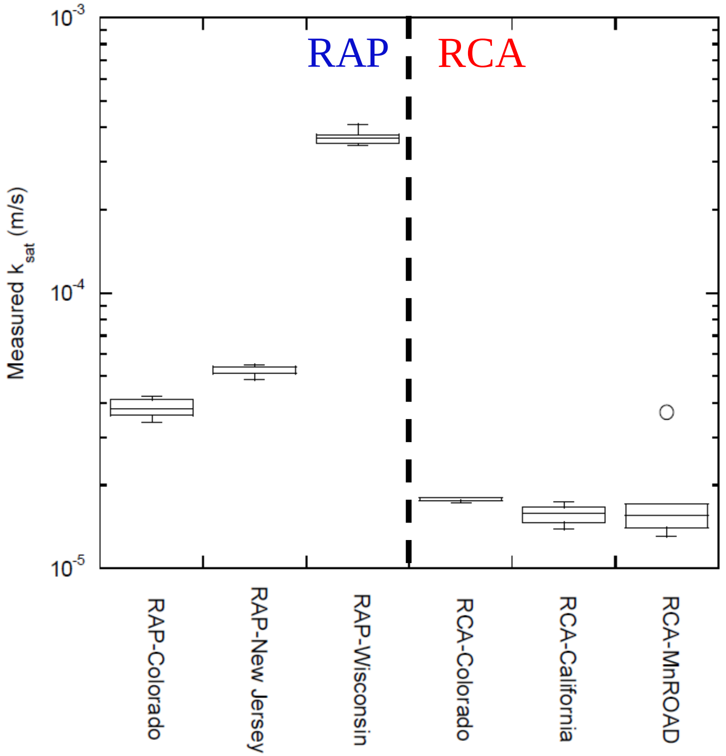
The water repellency of RAP (left) and RCA (right) (Edil et al. 2012)

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Hydraulic Properties

- k_{sat} ➔ RAP > RCA (Nokkaew et al. 2012)
  - RAP - 3.8 x 10^{-5} to 3.7 x 10^{-4} m/s
  - RCA ~1.8 x 10^{-5} m/s
- Unsaturated hydraulic conductivity
  - Hysteresis
  - Wetting - Drying



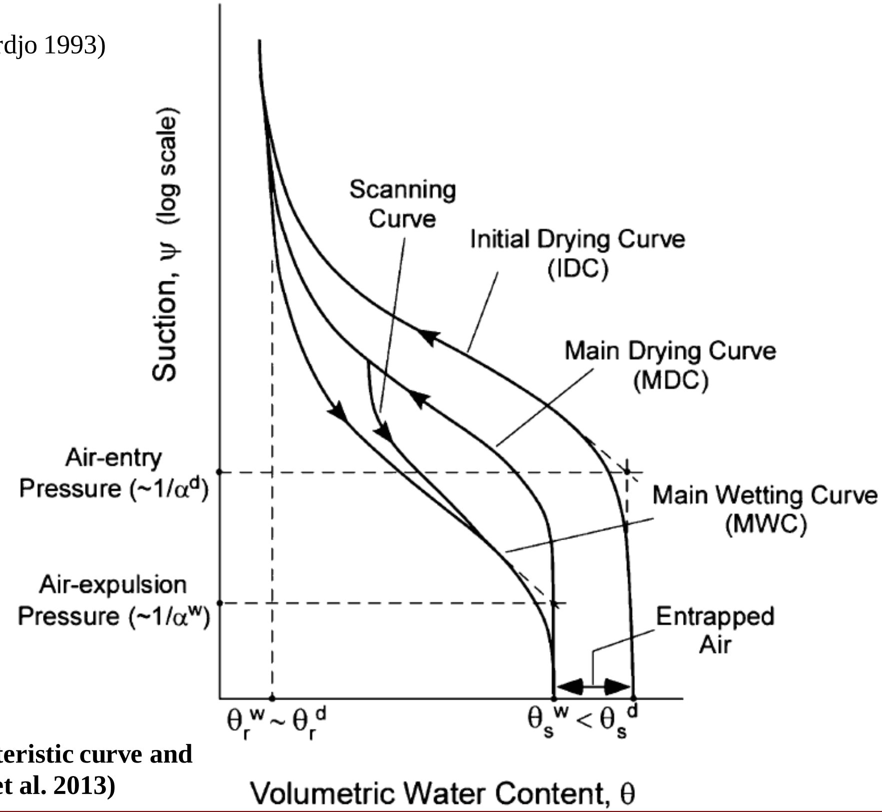
k_{sat} of RAP and RCA materials (Nokkaew et al. 2012)

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Hydraulic Properties

- Water content – drying > wetting (Likos et al. 2013)
- Air-entry pressure (Ψa) (Fredlund and Rahardjo 1993)
- Difficulty of wetting curve
- Contact angle – matric suction
  - + suction due to > 90° (RAP)
  - - suction due to ~ 0 ° (RCA)
- Contact angles – Ψa
  - Angle ↓, Ψa ↑



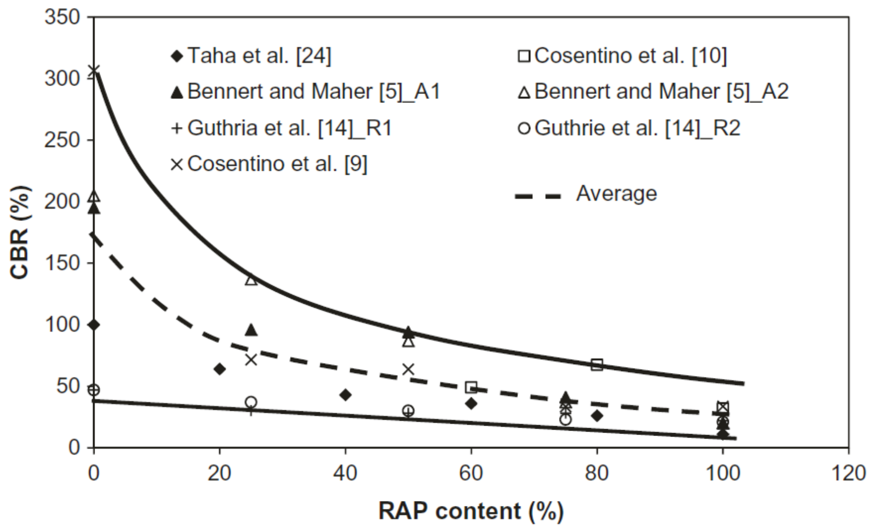
Soil water characteristic curve and hysteresis (Likos et al. 2013)

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Strength Properties

- CBR ➔ RAP < virgin aggregates (Bennert and Maher 2005; Guthrie et al. 2007)
- Asphalt content – bonding ↓, interlocking ↓ (Ooi et al. 2010; Taha et al. 1999)
- Lack of fines (Sayed et al. 1993)



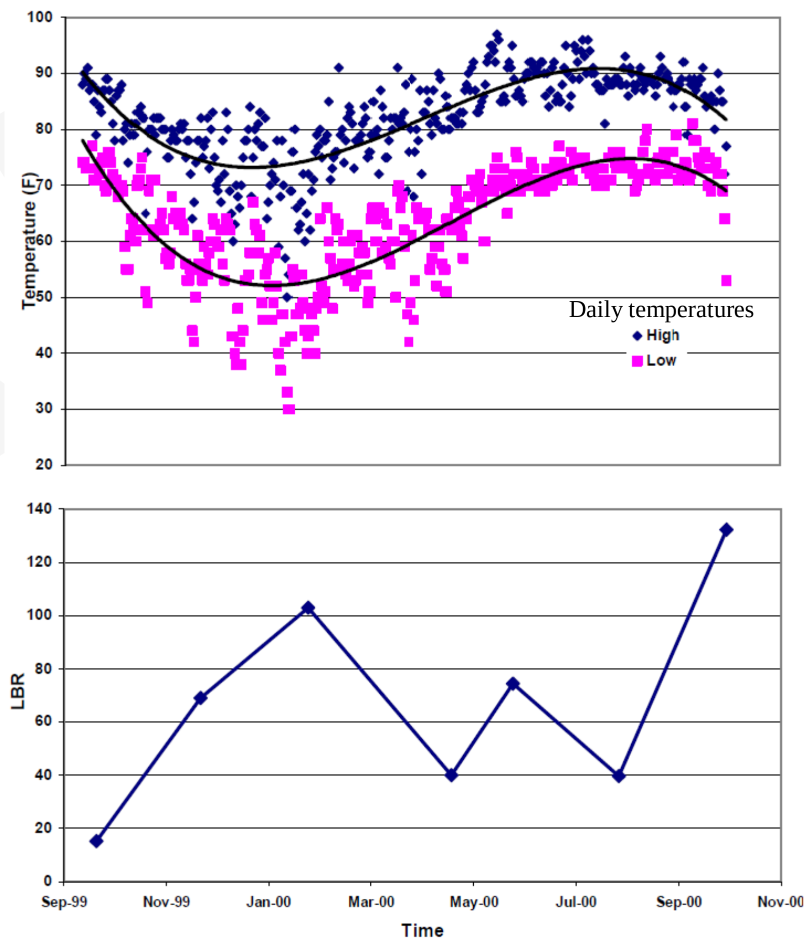
CBR values of the blends with different RAP contents (Thakur and Han 2015)

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Strength Properties

- Compaction at higher temperature (Montemayor 1998)
  - Max dry density ↑
  - Limerock Bearing Ratio – LBR ↑ (LBR = 1.25*CBR)
- Ambient temperature (Cosentino and Kalajian 2001)
  - Temperature ↑, LBR ↓



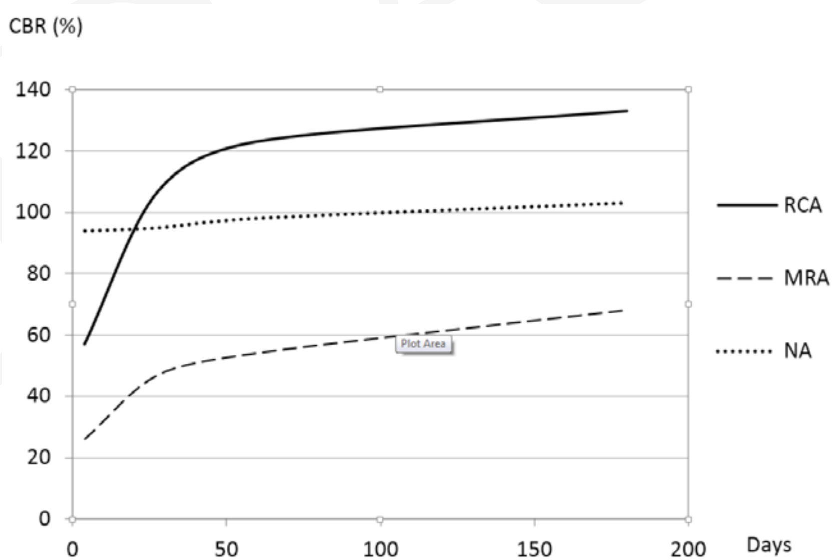
Changes in LBR of RAP with temperature (Cosentino and Kalajian 2001)

LITERATURE REVIEW

Engineering Properties of RAP, RCA and LSSB

Strength Properties

- Test method for RCA (Jayakody et al. 2012)
  - Unsoaked – Lower CBR
  - Soaked – Higher CBR
- Cementation of unhydrated cement (Garach et al. 2015; Bestgen et al. 2016a)



The effect of soaking period on the CBR of RCA (Garach et al. 2015)
NA – natural aggregates
MRA – mixed recycled aggregates

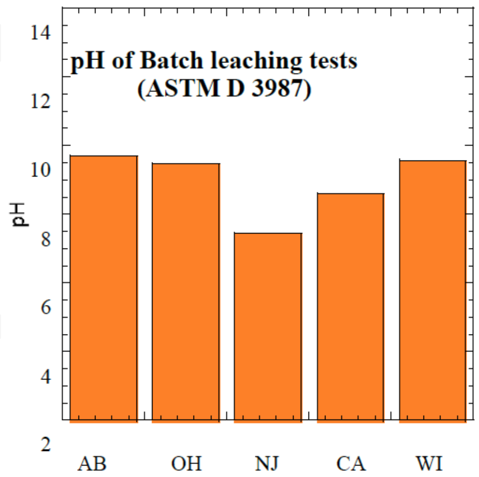
LITERATURE REVIEW

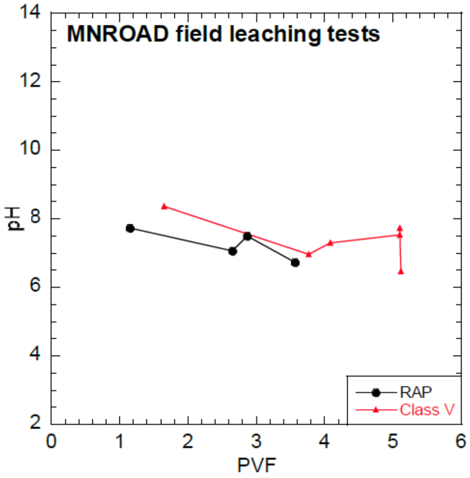
Environmental Properties of RAP

- Oxidation of asphalt ➔ age hardening (Roberts et al. 1996)

pH Characteristics

- Batch leaching tests ➔ 8.59 to 9.58 (Shedivy et al. 2012)
  ➔ about 9.67 (Kang et al. 2011)
  ➔ 8 to 10.5 (Edil et al. 2012)
- Field leaching tests ➔ about 8 (Edil et al. 2012)





pH of RAPs from batch leaching tests and field leaching tests (Edil et al. 2012)

LITERATURE REVIEW

Environmental Properties of RAP

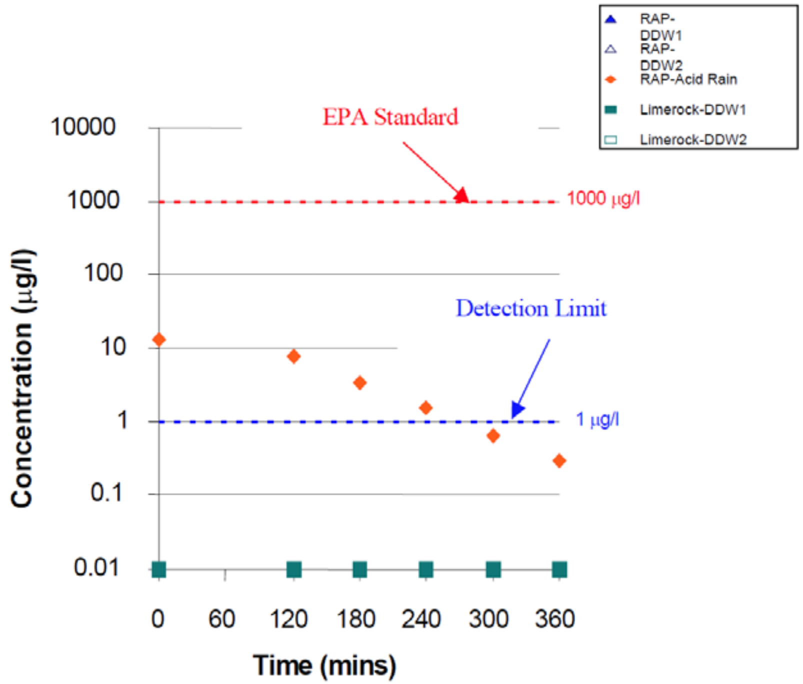
Heavy Metal Leaching Characteristics

- Tire residuals, corrosion of steel crash barriers, or brake pad/disc residuals (Muschack 1990; Hewitt and Rashed 1990)
- Main heavy metals (Hoppe et al. 2015; Edil et al. 2012)
  - Arsenic (As)
  - Aluminum (Al)
  - Cadmium (Cd)
  - Chromium (Cr)
  - Lead (Pb)
  - Silver (Ag)
  - Antimony (Sb)
  - Selenium (Se)

Environmental Properties of RAP

Heavy Metal Leaching Characteristics

- No environmental issue
- ≤ the EPA drinking water standards (Edil et al. 2012; Cosentino et al. 2003; Shedivy et al. 2012)
- Liquid type
  - Distilled-deionized water (DDW)
  - Synthetic acid rain (SAR)
- Time-dependent (Cosentino et al. 2003)
  - Time ↑, concentration ↓



Column leaching test results of cadmium (Cd) with different test fluids (Cosentino et al. 2003)

LITERATURE REVIEW

Environmental Properties of RAP

Poly-Aromatic Hydrocarbons (PAHs) Leaching Characteristics

- Incomplete burning of organic compounds
- Tire residuals, exhaust gasses, gasoline or diesel fuels (Takada et al., 1990; Baek et al., 1991; Sadler et al., 1999; Brandt et al., 2001; Kriech et al., 2002)
- Important PAHs
  - Acenaphthylene
  - Benzo(a)anthracene
  - Benzo(ghi)perylene
- No environmental issue (Hoppe et al. 2015; Shedivy et al. 2012)

LITERATURE REVIEW

Environmental Properties of RCA

- Major environmental concerns
  - Alkalinity
  - Heavy metal leaching
    - Cement paste (Van Dam et al. 2011; Engelsen et al. 2010)
    - Other cement additives such as fly ash (Cetin et al. 2012)
- Deicing applications ➔ chloride (ACPA 2009)
  - Corrosion of steel pipes
  - Durability

➔ Coarse-grained RCA

- Alkali-silica reactions (Van Dam et al. 2011)
  - No high concern
  - Porous structure

LITERATURE REVIEW

Environmental Properties of RCA

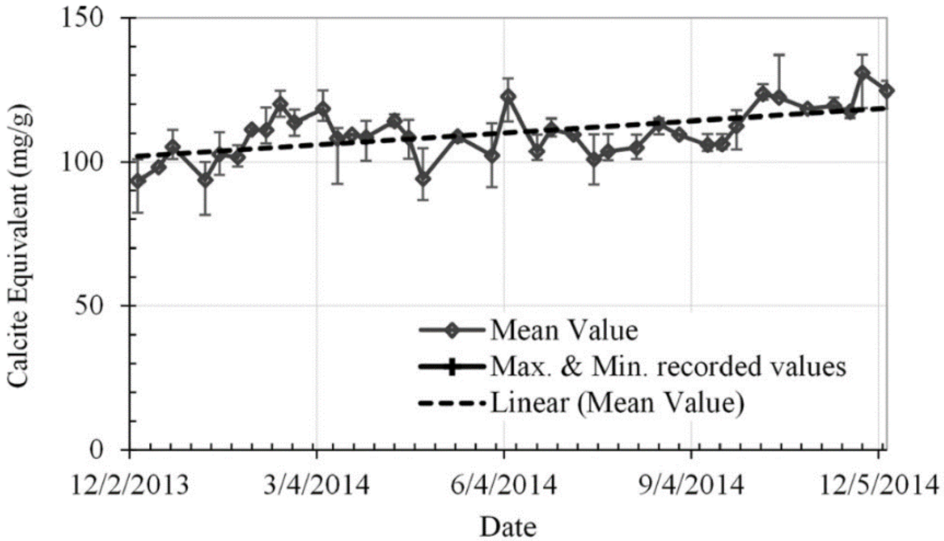
pH Characteristics

- Alkalinity
  - CaO and Ca^{2+} in cement paste (Cetin et al. 2013)
- Influence on heavy metal leaching (Engelsen et al. 2012; Bestgen et al. 2016a)
- pH ~ 10.5 – 13 (Steffes 1999; Chen et al. 2013; Abbaspour et al. 2016)
- Carbonation – exposure to atmosphere (Garrabrants et al. 2004; Gervais et al. 2004)
  - Calcium carbonate (calcite – $CaCO_3$)
  - pH ↓
  - Heavy metal leaching ↓
  - Stockpiled > freshly crushed (Abbaspour et al. 2016)

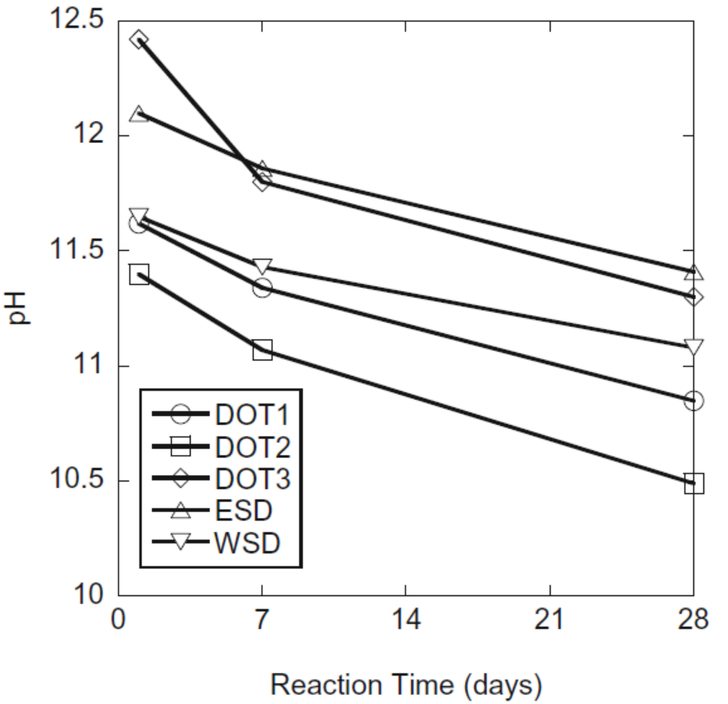
LITERATURE REVIEW

Environmental Properties of RCA

pH Characteristics



Change in carbonation over time (Abbaspour et al. 2016)



Change in pH of different RCAs over time (Bestgen et al. 2016b)

LITERATURE REVIEW

Environmental Properties of RCA

Heavy Metal Leaching

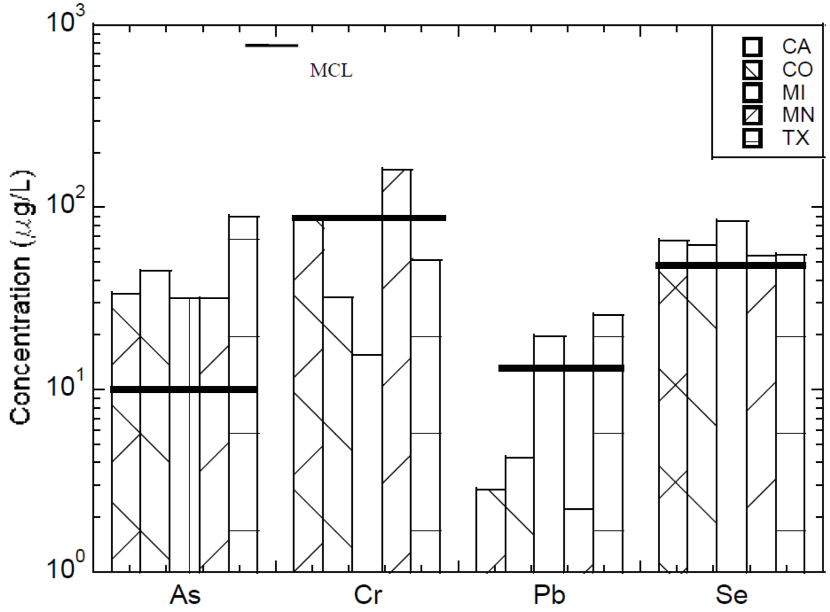
- Main heavy metals (Engelsen et al. 2009; Engelsen et al. 2010; Edil et al. 2012; Bestgen et al. 2016b; Abbaspour et al. 2016).
  - Aluminum (Al)
  - Silicon (Si)
  - Calcium (Ca)
  - Magnesium (Mg)
  - Chromium (Cr)
  - Copper (Cu)
  - Iron (Fe)
  - Zinc (Zn)

LITERATURE REVIEW

Environmental Properties of RCA

Heavy Metal Leaching

- Laboratory – more controlled than field
- Cement properties – sources
- Higher potential than RAP



Concentrations of different metals and maximum contaminant levels (MCLs) for EPA drinking water standards (Edil et al. 2012)

LITERATURE REVIEW

Environmental Properties of RCA

Heavy Metal Leaching

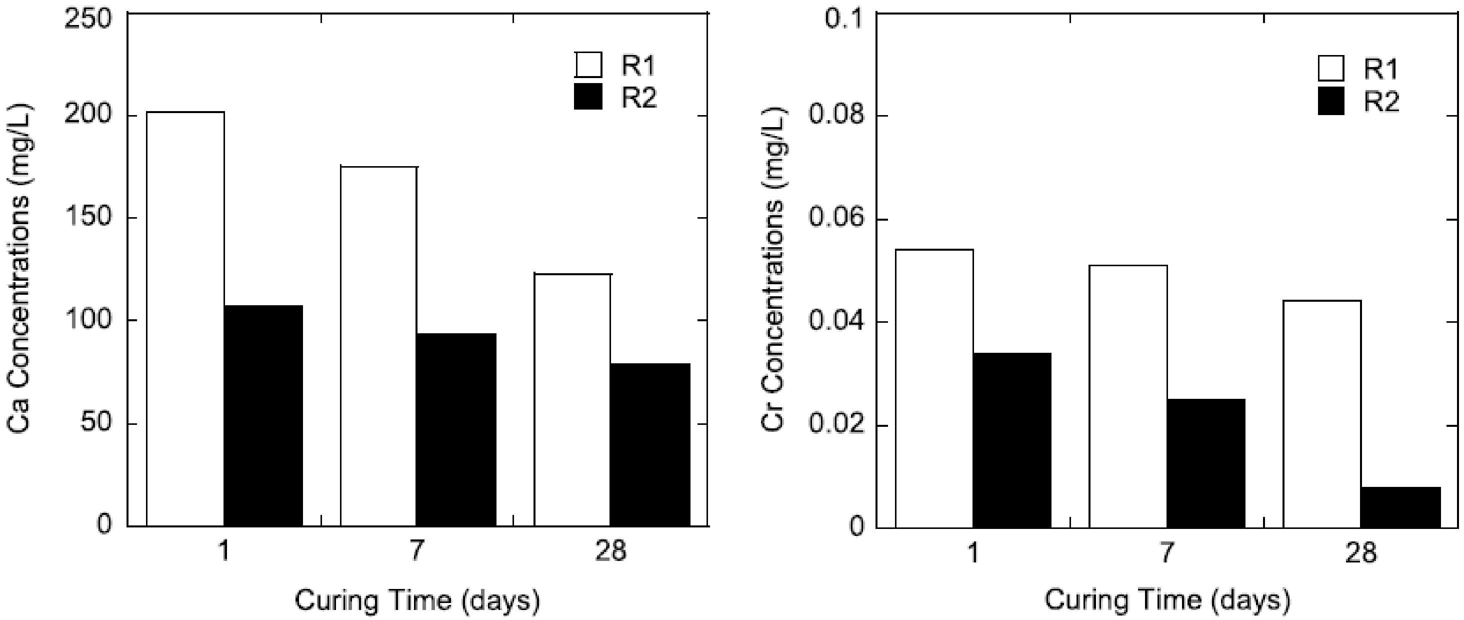
- Other factors affecting leaching (Bestgen et al. 2016a-b; Abbaspour et al. 2016)
  - Aging
  - L/S ratio
  - Gradation
- Total metal content ➔ not significant (Bestgen et al. 2016b)
- Aging ↑, metal concentration ↓ (Bestgen et al. 2016a)
- L/S ratio ↑, metal concentration ↓ (Bestgen et al. 2016a)
- Fines content ↑, metal concentration ↑- ↓ (Edil et al. 2012; Chen et al. 2013; Bestgen et al. 2016a)
  - ↑ because of increased interaction
  - ↓ because of carbonation

LITERATURE REVIEW

Environmental Properties of RCA

Heavy Metal Leaching

- Aging ↑, metal concentration ↓ (Bestgen et al. 2016a)



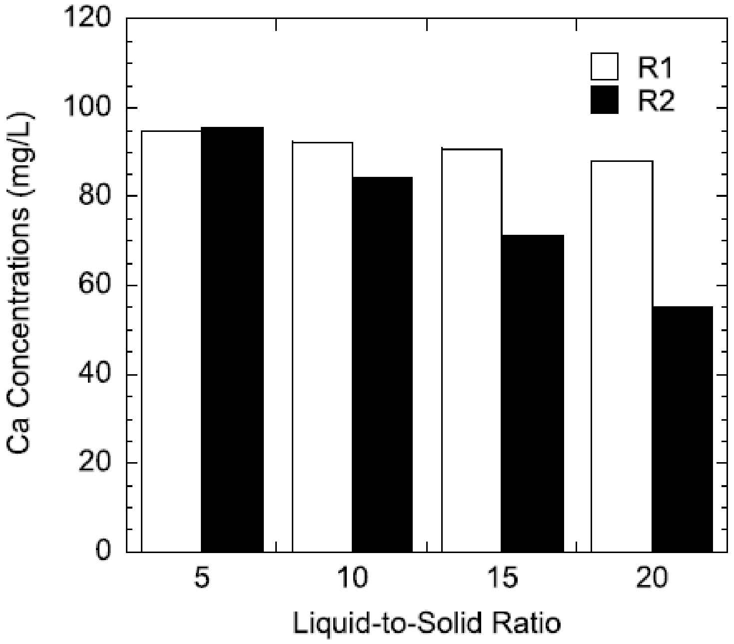
Change in concentrations of Ca and Cr with curing time (Bestgen et al. 2016a)

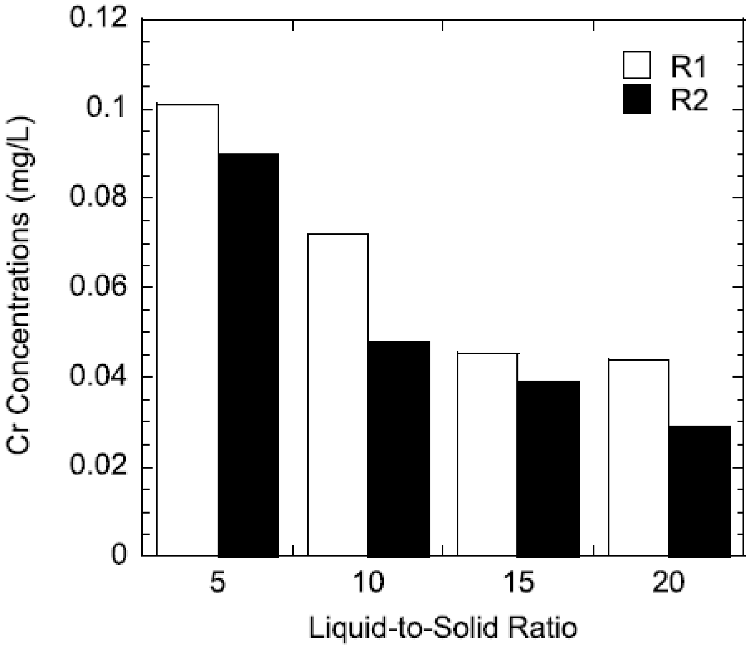
LITERATURE REVIEW

Environmental Properties of RCA

Heavy Metal Leaching

- L/S ratio ↑, metal concentration ↓ (Bestgen et al. 2016a)





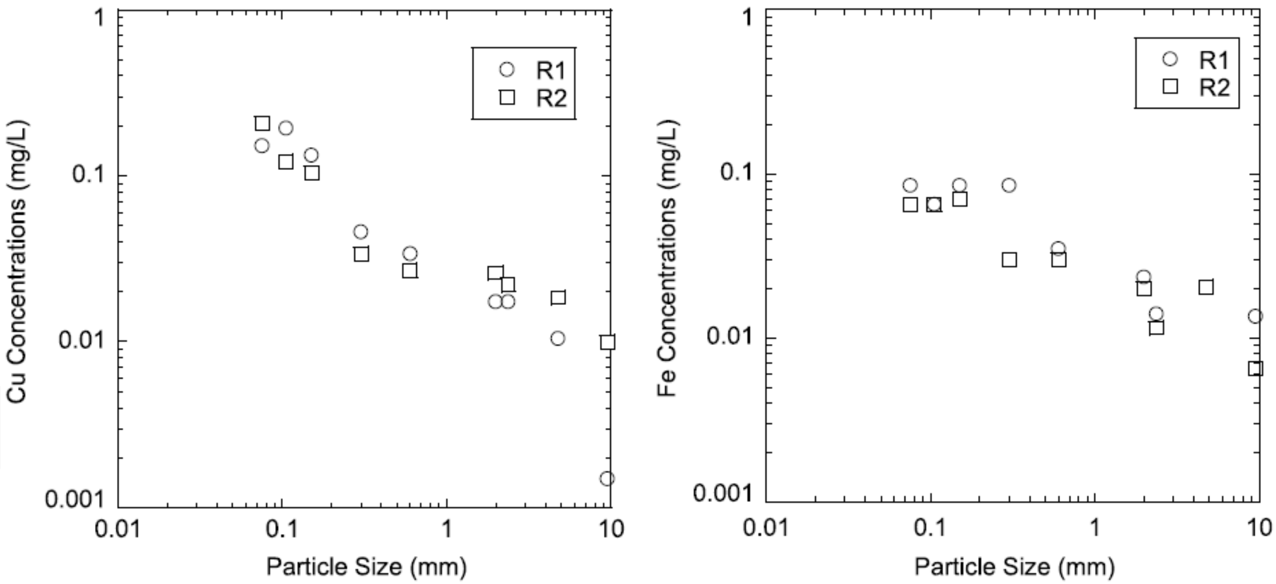
Effects of liquid-to-solid ratio on concentrations of Ca and Cr in leachates of different RCAs (Bestgen et al. 2016a)

LITERATURE REVIEW

Environmental Properties of RCA

Heavy Metal Leaching

- Fines content ↑, metal concentration ↑ (Edil et al. 2012; Bestgen et al. 2016a)



Effect of particle size on the concentrations of metals in leachates of different RCAs (Bestgen et al. 2016a)

- Fines content ↑, metal concentration ↓ (Chen et al. 2013)

LITERATURE REVIEW

Environmental Properties of RCA

Heavy Metal Leaching

- Tufa formation (Ceylan et al. 2013; Abbaspour et al. 2016)
  - Precipitation of heavy metals
- Drainage quality ↓ (Phan 2010 and White et al. 2008)
- Coarse-grained material (> No 4. sieve) (Gupta and Dollimore 2002)
- Washing RCA prior to application (Snyder and Bruinsma 1996)

Clean pipe (left) and partially-clogged pipe (right) (Ceylan et al. 2013)

LITERATURE REVIEW

Geosynthetic Applications

- Pavements (Erickson and Drescher 2001; Zornberg 2017)
  - Geotextiles – woven & nonwoven
  - Geogrids – biaxial & multiaxial
- Main functions (Zornberg 2012)
  - Separation
  - Filtration
  - Reinforcement
- Base/subbase or subbase/subgrade (Zornberg 2017)

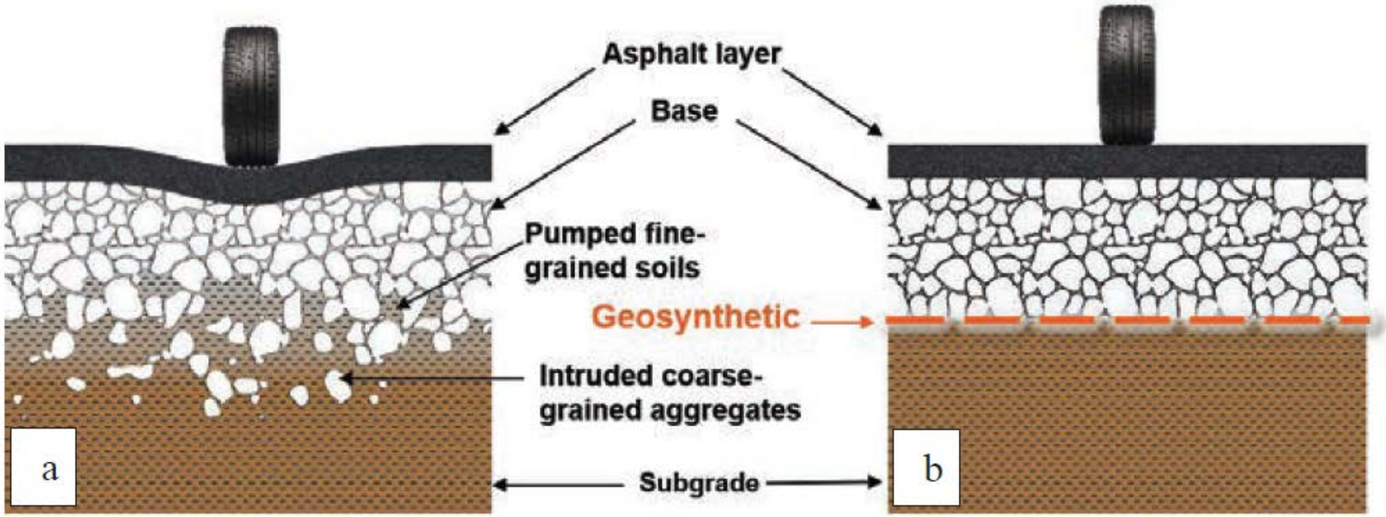
Geotextiles[1] (left) and geogrids[2] (right)
[1]https://study.com/academy/lesson/what-is-geotextile-fabric-definition-types.html
[2]https://commons.wikimedia.org/wiki/File:Geogrids.JPG*

LITERATURE REVIEW

Geosynthetic Applications

Separation

- Movement of granular base layers into soft subgrade
- Contamination of subgrade ➔ structural support ↓



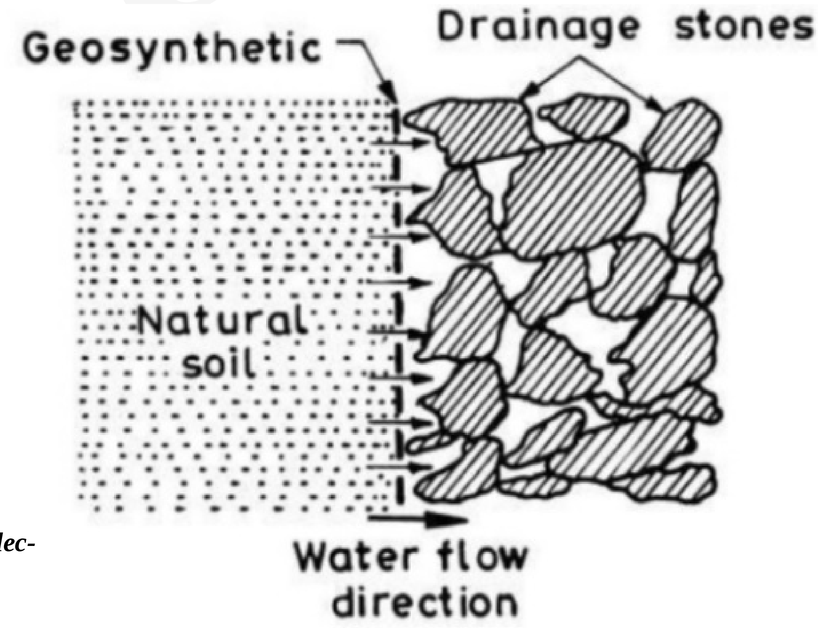
Separation function of geosynthetics (Zornberg 2017)

LITERATURE REVIEW

Geosynthetic Applications

Filtration

- Movement of subgrade soils into base layer
  - Upward movement of water
- Fines content of base layers ↑ (Zornberg 2017)
  - Shear strength ↓
  - Permeability ↓
  - Frost-susceptibility ↑



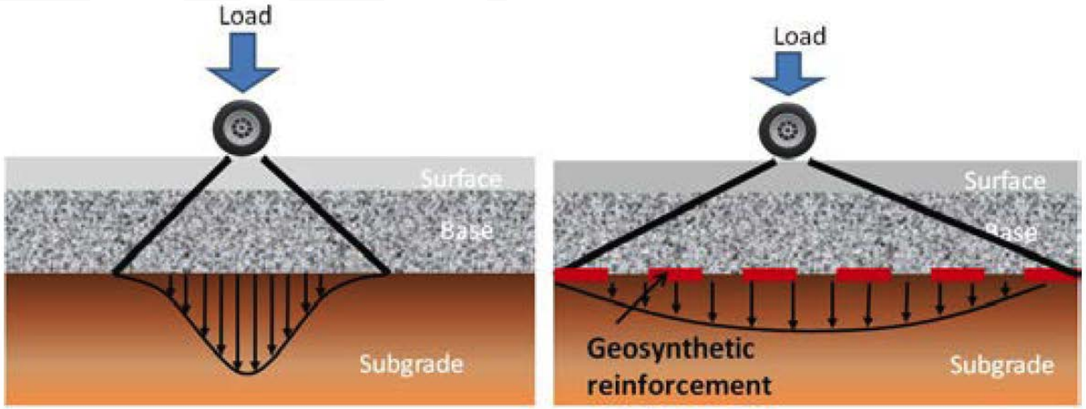
Filtration function of geosynthetics ***(https://www.slideshare.net/samirsinhparmar/lec-2-functions-and-selection-of-geosynthetics)***

LITERATURE REVIEW

Geosynthetic Applications

Reinforcement

- Geosynthetics (Holtz et al. 1998; Perkins et al. 2005; Zornberg 2012)
  - Bearing capacity ↑
  - Lateral resistance
  - Permanent deformation ↓
  - Load distribution ↑
- Base layer thickness ↓ (Perkins et al. 2005)



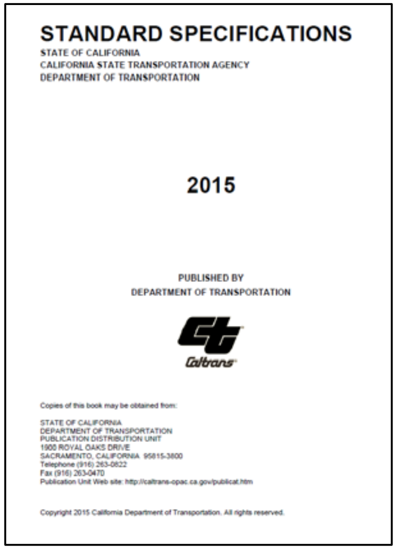
Load distribution mechanisms of (a) unreinforced pavement, and (b) reinforced pavement (Zornberg 2012)

LITERATURE REVIEW

Selected Practices of State DOTs

California DOT

- Crushed AC & PCC for base & subbase
  - Caltrans Standard Specifications 2015
    - Before 2006 ➔ up to 50% of recycled materials
    - After 2006 ➔ up to 100%
- Section 25 - Subbase
  - Class 1, Class 2, or Class 3
  - Quality control – sand equivalent[1], R-value[2]
- Section 26 – Base
  - Class 2 or Class 3
  - Quality control – sand equivalent[1], R-value[2]



STANDARD SPECIFICATIONS
STATE OF CALIFORNIA
CALIFORNIA STATE TRANSPORTATION AGENCY
DEPARTMENT OF TRANSPORTATION

2015

PUBLISHED BY
DEPARTMENT OF TRANSPORTATION

Caltrans

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Publication Unit Web site: http://caltrans-opac.ca.gov/publicat.htm

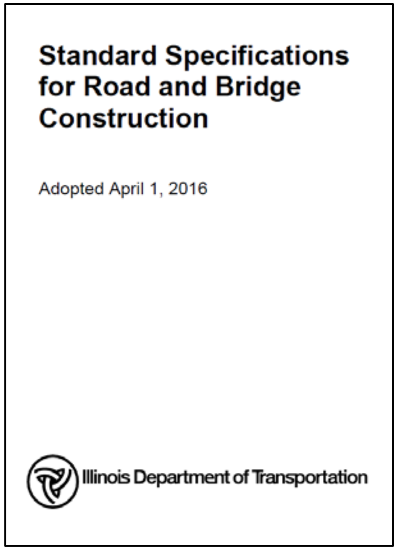
[1]To observe the relative presence of sand vs clay. Higher value indicates less clay.
[2]To measure the response of compacted specimen to a vertical loading.

LITERATURE REVIEW

Selected Practices of State DOTs

Illinois DOT

- Crushed PCC for base & subbase
- RAP for subbase only
  - IDOT Standard Specifications for Road and Bridge Construction 2016
- Section 1004
  - RCA – CA 6 or CA 10
  - Quality control
    - LA abrasion (class D) < 45%
    - Deleterious materials (class C) – Shale, clay lumps, soft fragments
- Section 303
  - RAP – subbase (< 40%)
  - CS01 (< 8 in), CS02 (< 6 in), RR01 (< 3 in)


Standard Specifications for Road and Bridge Construction

Adopted April 1, 2016

Illinois Department of Transportation

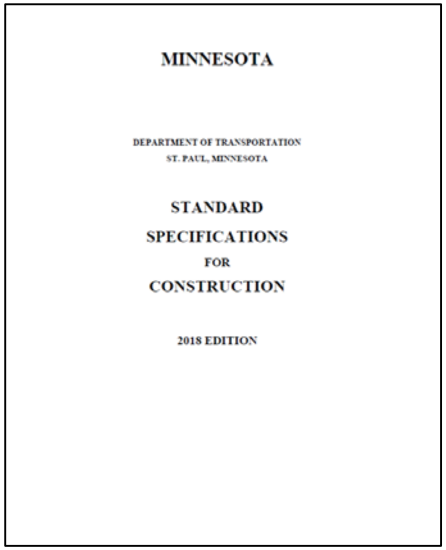
LITERATURE REVIEW

Selected Practices of State DOTs

Minnesota DOT

- RAP & RCA for base
  - MnDOT Standard Specifications for Construction 2018
- Section 3138
  - Same as natural aggregates
  - RAP < 25% (by volume) ➔ natural aggregate
  - RAP > 25% (by volume) ➔ recycled blend
- Different gradation specifications for different blends
- Blending at the crushing site (no stockpiles)

(McGarrah 2007)


MINNESOTA

DEPARTMENT OF TRANSPORTATION
ST. PAUL, MINNESOTA

STANDARD
SPECIFICATIONS
FOR
CONSTRUCTION

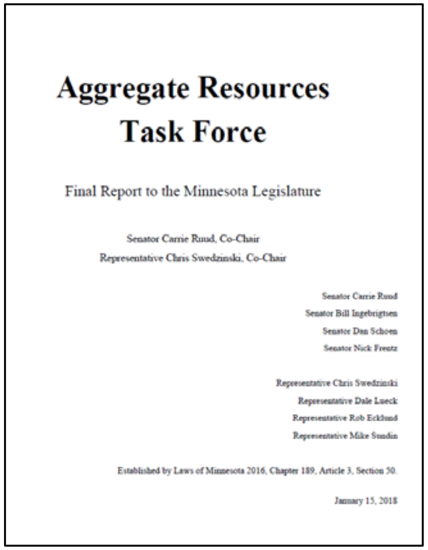
2018 EDITION

LITERATURE REVIEW

Selected Practices of State DOTs

Minnesota DOT

- Aggregate Resources Task Force (ARTF)
- To increase the efficiency
  - Selecting & using virgin aggregate sources
- Aggregate Mapping Program
  - Minnesota Department of Natural Resources (DNR)
- Mapping tool
  - Practical to locate high-quality aggregate sources
  - Easy access to the aggregate deposits
- 61 counties


Aggregate Resources Task Force

Final Report to the Minnesota Legislature

Senator Carrie Ruud, Co-Chair
Representative Chris Swedzinski, Co-Chair

Senator Carrie Ruud
Senator Bill Ingebrigtsen
Senator Dan Schoen
Senator Nick Frentz

Representative Chris Swedzinski
Representative Dale Lueck
Representative Rob Ecklund
Representative Mike Sundin

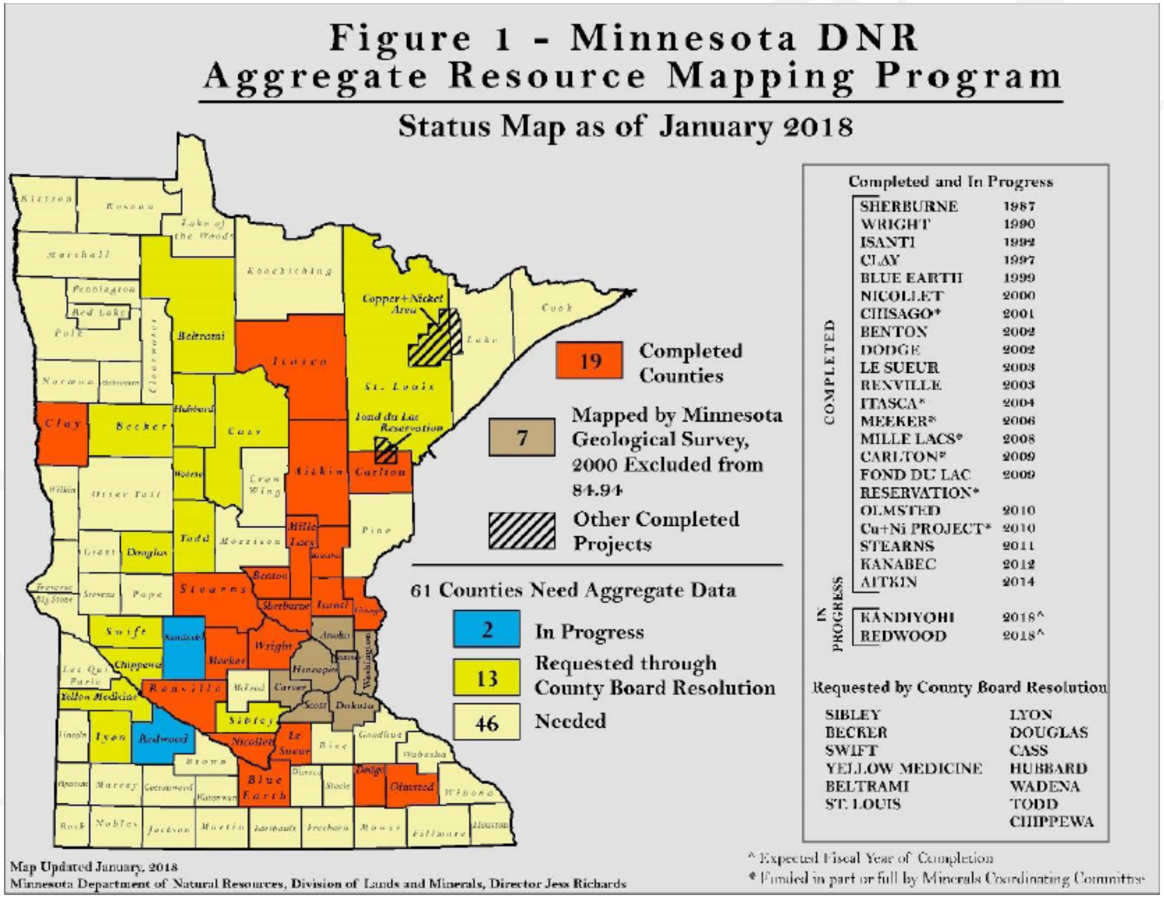
Established by Laws of Minnesota 2016, Chapter 189, Article 3, Section 50.

January 15, 2018

LITERATURE REVIEW

Selected Practices of State DOTs

Minnesota DOT

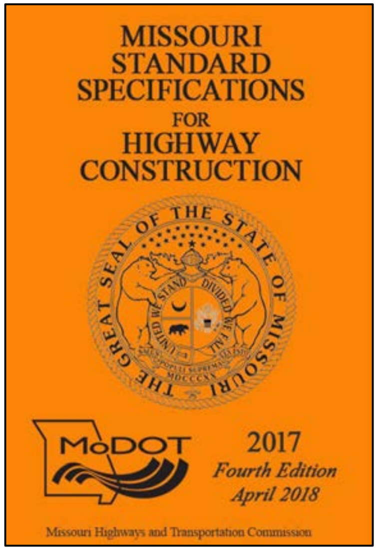


LITERATURE REVIEW

Selected Practices of State DOTs

Missouri DOT

- Reclaimed asphalt & concrete for base
  - MoDOT Standard Specifications for Highway Construction 2018
- Type 1, Type 5, or Type 7 (Base)
- Section 1007
  - Deleterious materials < 15%
  - PI (passing No. 40 sieve) < 6
- Section 303 (Rock base)
  - Stones containing < 10% (by weight) sand & shale
  - Max particle size – layer thickness
    - Max 12 in. for 18-in rock base
    - Max 9 in. for 12-in rock base



LITERATURE REVIEW

Selected Practices of State DOTs

Wisconsin DOT

- Reclaimed asphalt & crushed concrete for base
  - WisDOT Standard Specifications for Highway and Structure Construction 2018
- Reclaimed asphalt ➔only for well-graded (dense) 1 ¼-inch agg.
- Crushed concrete ➔ dense ¾-inch, 1 1/4-inch, and 3-inch agg.
- No deleterious materials
- Section 301
  - > 75% of reclaimed asphaltic pavement
  - > 90% crushed concrete with < 10% asphaltic pavement


STATE OF WISCONSIN

WISCONSIN DEPARTMENT OF TRANSPORTATION

STANDARD SPECIFICATIONS
FOR
HIGHWAY AND STRUCTURE
CONSTRUCTION

2018 Edition
Effective with December 2017 letting

The annotations, shown in boxed text, in this 2018 edition of the standard specifications identify substantive changes made since the 2017 edition. A brief explanation of each change is shown both in the table of contents and again adjacent to each revised passage. These annotations are not part of the contract.

LITERATURE REVIEW

Selected Practices of State DOTs

Wisconsin DOT

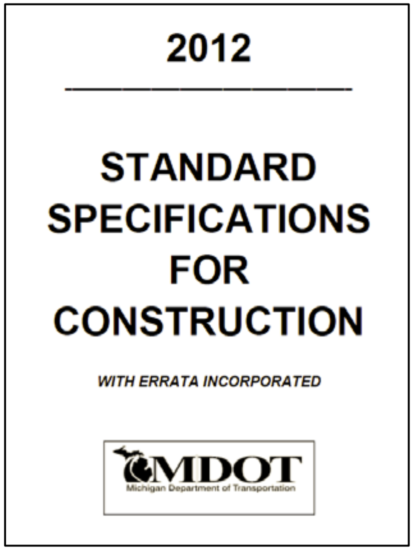
- Section 305 - base
  - Reclaimed asphalt – visual inspection
  - Crushed concrete - gradation specification
- Section 312 – subgrade correction (subbase)
  - Crushed stone & crushed concrete
  - No deleterious materials
  - Gradation specification (max 5 in)

LITERATURE REVIEW

Selected Practices of State DOTs

Michigan DOT

- Crushed concrete for base
  - MDOT Standard Specifications for Construction 2012
- Section 902
  - Gradation (21AA, 21A, 22A, 23A)
  - Quality (% of crushed material, LA abrasion < 50%)
  - < 5% of brick, wood, plaster
  - Steel pieces
- Environmental concerns
  - Interlayer between base & subgrade (min 12 in)
  - Geotextile liner or geomembrane



LITERATURE REVIEW

Recommendations

- Characteristics of asphalt binder under various temperature
- Long-term moisture susceptibility of RCA
- The effect of temperature on compaction characteristics of RAP
- Engineering properties of RAP materials compacted at different temperatures.
- A maximum time to complete compaction for RCA
- Effects of angularity and elongation of materials
- Water retention curve characteristics of materials
- Heavy metal leaching mitigation mechanisms
- In-depth cost analysis

TECH TRANSFER

Draft Outline

- Introduction – reasons
- General uses of the materials
- Properties of base and subbase layers with the materials
- State Specifications
- Sustainability
- Design guidelines
- Recommendations

Questions ?

- Scope of the report ?
- Single or separate reports for recycled materials and LSSB?

CP ROAD MAP

"Moving Advancements into Practice"

MAP Brief March 2016

Best practices and promising technologies that can be used now to enhance concrete paving

Concrete Pavement Recycling and the Use of Recycled Concrete Aggregate in Concrete Paving Mixtures

www.cproadmap.org

March 2016

ROAD MAP TRACK 12

PROJECT TITLE
Concrete Pavement Recycling and the Use of Recycled Concrete Aggregate in Concrete Mixtures

TECHNICAL WRITER
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SPONSORS
Federal Highway Administration
National Concrete Consortium

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Engineering Consultant

Introduction

Concrete pavement recycling is a relatively simple process that involves breaking, removing, and crushing hardened concrete from an acceptable source to produce recycled concrete aggregate (RCA) (see figure 1), a granular material that can be produced for any application for which virgin aggregate might be used (ACPA 2009).

Concrete recycling has been used extensively in Europe since the 1940s and in the U.S. since the 1970s (NHI 1998). Concrete recycling for paving applications is now performed in at least 41 states (FHWA 2004). Annual production of RCA in the U.S. from all sources (both pavements and demolition debris) was recently reported as about 140 million tons (CDRA 2014).

The recycling of paving materials (including concrete pavement) into new paving applications is supported by the Federal Highway Administration, which states that "reusing the material used to build the original highway system makes sound economic, environmental, and engineering sense" (FHWA 2002; also Hall et al. 2007, Van Dam et al. 2015).

Reasons for Concrete Pavement Recycling

There are many good reasons to recycle concrete pavement, including the increased demand for quality aggregates in the face of limited resources, the reduced availability of landfill space, and the adoption of sustainable construction practices. Economics is a component of sustainability, and concrete recycling offers the potential for major savings in the costs of aggregate, which comprises 20%–30% of the cost of pavement construction materials and supplies (Halm 1980) and 10%–15% percent of total construction costs (excluding engineering and right-of-way acquisition). Cost savings from concrete pavement recycling vary but have been reported to be as high as $5 million on a single project (CMRA 2006).

In addition, concrete pavement recycling is a smart and environmentally sustainable choice that conserves aggregate and other resources, reduces unnecessary consumption of limited landfill space, saves energy, reduces greenhouse gas emissions, and captures carbon dioxide (CO_2) from the atmosphere. Concrete recycling can eliminate the need for mining or extracting new virgin aggregates, and can reduce haul distances and fuel consumption associated with both aggregate supply and concrete slab disposal.

Uses of RCA

RCA has been successfully used in many paving applications, including new concrete paving mixtures for single- or two-lift concrete pavements, HMA paving mixtures, bound and unbound subbase applications (e.g., cement-treated and granular base), drainage layers, fill

Figure 1. Photo of stockpiled coarse RCA

http://www.cproadmap.org/publications/MAPbriefMarch2016.pdf

TO-DO LIST

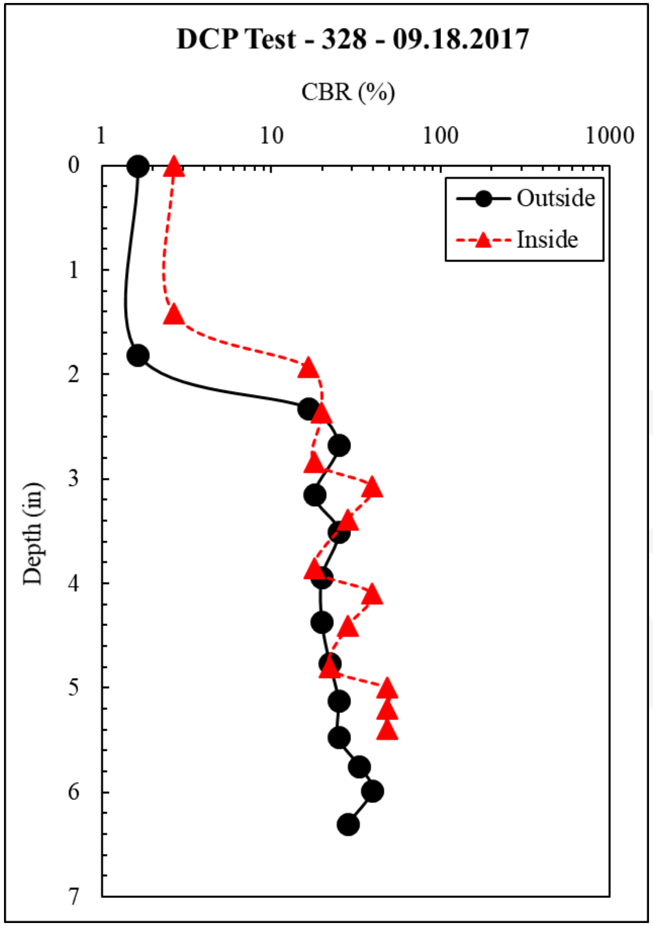
Laboratory study

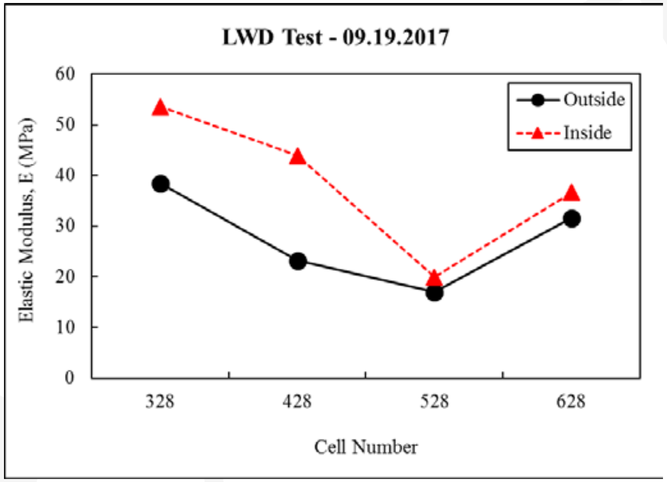
- **Iowa State University**
  - Soil classification
  - Image analysis
  - Proctor & gyratory compaction
  - Asphalt & cement content determination
  - Contact angle measurement

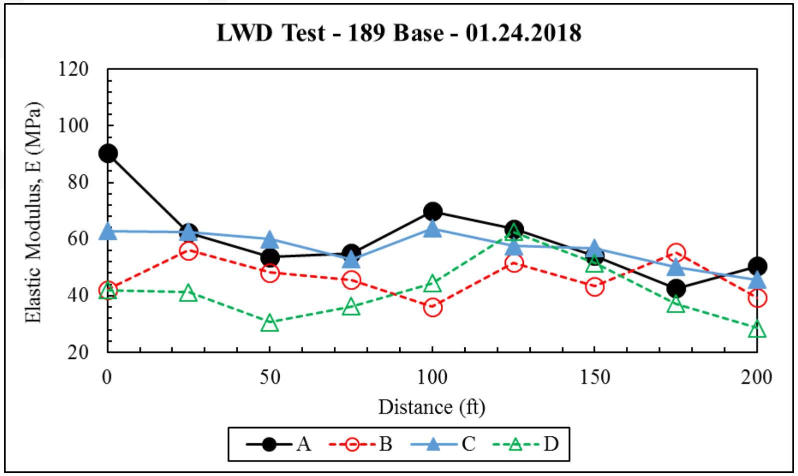
- **University of Wisconsin-Madison**
  - Soil classification
  - Soil-water characteristic curve
  - Permeability

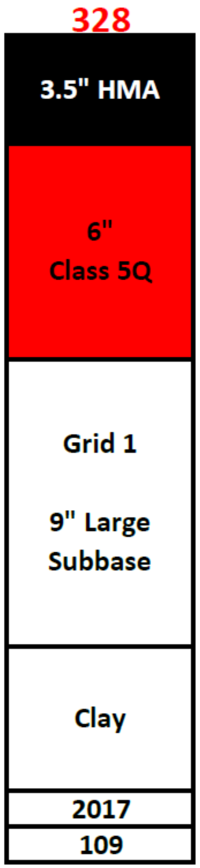
DCP DATA ANALYSIS

*Colored graphs





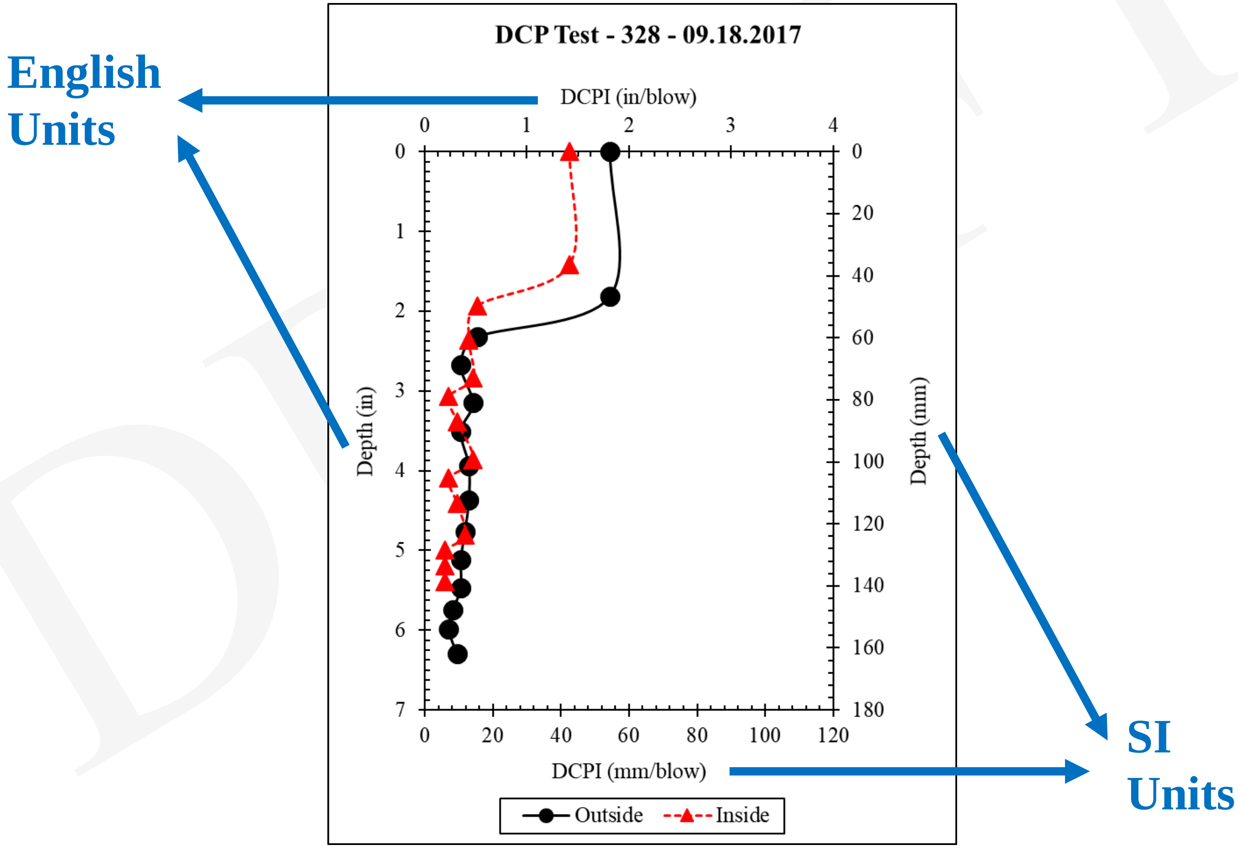




DCP DATA ANALYSIS

DCP Test – 328 - 09.18.2017

*SI and English Units



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SCHEDULE

TASKS	MONTHS																																
	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
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Task 9																																	

Thank You!

QUESTIONS??