

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

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MnDOT Project TPF-5(341)

Monthly Meeting

May 3rd, 2018

RESEARCH TEAM

Iowa State University

- Principal Investigator – Bora Cetin
Assistant Professor – Department of Civil, Construction & Environmental Engineering
- Co-Principal Investigator – Ashley Buss
Assistant Professor – Department of Civil, Construction & Environmental Engineering
- Co-Principal Investigator – Halil Ceylan
Professor – Department of Civil, Construction & Environmental Engineering
- Co-Principal Investigator – Junxing Zheng
Assistant Professor – Department of Civil, Construction & Environmental Engineering
- Research Personnel – Haluk Sinan Coban
PhD Student – Department of Civil, Construction & Environmental Engineering

University of Wisconsin-Madison

- Co-Principal Investigator – William Likos
Professor – Department of Civil and Environmental Engineering
- Co-Principal Investigator – Tuncer B. Edil
Professor Emeritus – Department of Civil and Environmental Engineering

NRRA Members (Agency Partners)

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

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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

OUTLINE

- Literature Review – Reminder
- Materials
- Tech Transfer Drafts
- Field Testing

DRAFT

MATERIALS

Bucket List - 04.10.2018 - Iowa State University

Bucket #	Cell	MnROAD ID	Description
1	185	18517SS010	sandy subgrade soil - stations on rover
2	186	18617SS010	sandy subgrade soil - stations on rover
3	188	18817SS010	clayey subgrade soil - stations on rover
4	127	12717SS009	Subgrade soil post-excavation pre-rip top 18"
5		12717SS010	Subgrade soil post-excavation pre-rip top 18"
6		12717GS005	Class 6; green Menard's bucket
7		12717GS006	Class 6; green Menard's bucket
8		12717GS007	Class 6; green Menard's bucket
9		12717GS008	Class 6; green Menard's bucket
10	227	22717SS009	Subgrade soil post-excavation pre-rip top 18"
11		22717SS010	Subgrade soil post-excavation pre-rip top 18"
12	128	12817SS009	Subgrade soil post-excavation pre-rip top 18"
13		12817SS010	Subgrade soil post-excavation pre-rip top 18"
14	228	22817SS010	Subgrade soil post-excavation pre-rip top 18"
15		22817GS005	Class 5Q sampled from original X28 construction; green Menard's bucket
16		22817GS006	Class 5Q sampled from original X28 construction; green Menard's bucket
17		22817GS007	Class 5Q sampled from original X28 construction; green Menard's bucket
18		22817GS008	Class 5Q sampled from original X28 construction; green Menard's bucket

Bucket List - 01.19.2018 - Iowa State University

Bucket #	Cell	MnROAD ID	Description
1	185	18517GS001	
2		18517GS001	
3	186	18617GS001	
4		18617GS001	
5	188	18817GS001	
6		18817GS001	
7	189	18917GS001	
8		18917GS001	

Recycled Unbound Base				Large Subbase		Large Subbase and Geogrid Cells					
185	186	87	188	189	127	227	328	428	528	628	728
3.5" HMA	3.5" HMA		3.5" HMA	3.5" HMA	3.5" HMA	3.5" HMA	3.5" HMA	3.5" HMA	3.5" HMA	3.5" HMA	3.5" HMA
12" Coarse RCA	12" Fine RCA		12" Recycled Agg Base Class 6	12" Recycled Agg Base Class 6	6" Class 6	6" Class 6	6" Class 5Q	6" Class 5Q	6" Class 5Q	6" Class 5Q	6" Class 5Q
					18" Large Subbase	18" Large Subbase	Grid 1	Fabric Grid 1	Fabric Grid 2	Grid 2	9" Large Subbase
					1 lift	2 lifts	9" Large Subbase	9" Large Subbase	9" Large Subbase	9" Large Subbase	
3.5" Select Granular Borrow	3.5" Select Granular Borrow		3.5" Select Granular Borrow	3.5" Select Granular Borrow			Clay	Clay	Clay	Clay	Clay
Sand	Sand		Clay	Clay	Clay	Clay					

Gray color → received

Granular Borrow → will be taken from UTEP

LSSB → 1 barrel for ISU & UW-Madison

TECH TRANSFER DRAFTS

- Determining Pavement Design Criteria for Recycled Aggregate Materials
- Determining Pavement Design Criteria for Large Stone Subbase Materials



TECH TRANSFER "STATE OF PRACTICE" REPORT

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

MaDOT Project TPF-5(041)

PRINCIPAL INVESTIGATOR
Ben Cetin

PROJECT TECHNICAL ADVISORY COMMITTEE
Terry Beaudry
John Sukraner
Daphni Minkley
Ed Johnson
James Brimman
Tim Anderson
Jeff Henshall
Richard Endrey
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The NRRRA pooled fund exists to provide guidance for the Phase II MaDOT research program. Led by an Executive Committee of state DOT members, NRRRA will plan and oversee the entire lifecycle of MaDOT research, from the selection of research topics to communication and implementation of results. NRRRA will consist of five project teams: Flexible, Rigid, Geotechnical, Pavement Maintenance and Technology Transfer.

NRRRA members will help shape the MaDOT research program by providing the selection of research projects, disseminating research results, and helping agencies put the results into place.

Current MaDOT Agency Members



Develop Collaborate Research Implement

Determining Pavement Design Criteria for Recycled Aggregate Base Materials

Introduction

The performances of the layers beneath the pavement surface (aggregate base, subbase, and subgrade) are very important for the long-term pavement performance since they help distribute the vehicle loads in both rigid and flexible pavements (Little and Nair 2009). The aggregate base course is generally the first layer beneath the pavement surface course (Cosentino and Kalajian 2001). It is made of coarse-grained materials to provide a stiff and permeable layer (Schuettpelz et al. 2010; Hinder et al. 2014; Cetin et al. 2014; Edil and Cetin 2015). Adequately stiff aggregate base course reduces the deformations and increases the lifespan of the pavement (Edil et al. 2012). The high stiffness of aggregate base layers improves the stability of the sublayers by improving the vertical load distribution (Zornberg 2017). Generally, virgin aggregates (VA) are used for an aggregate base course in pavement systems (Perkins et al. 2005).

About 1.33 billion tons of VA were produced in the US in 2017, and about 76% of the materials were used for pavement construction (USGS 2018). The price of VA has increased due to the high demand, the depletion of natural sources and federal/local restrictions regarding material production (ACPA 2010). Using recycled aggregate base materials can help the environment by reducing the consumption of natural sources, improving waste utilization and decreasing the greenhouse gas emissions and energy consumption (Lee et al. 2010).

Recycled Aggregate Base Materials

Recycled asphalt pavement (RAP) (Figure 1) and recycled concrete aggregate (RCA) (Figure 2) have been used by some DOTs (Caltrans, IDOT, MaDOT, and WisDOT) in concrete hot mix asphalt (HMA) mixtures and in aggregate base applications. Old asphalt pavement surfaces are milled to a specific depth (depending on the surface course thickness) and processed to obtain RAP (Edil 2011).

Existing hardened concrete from old pavement surfaces or from other structures such as buildings and bridges is crushed. Then, construction debris and steel used as a reinforcement are removed and the end product

is called RCA (Edil et al. 2012; LRBD 2016). RAP and RCA materials can be either used at the same construction site or stockpiled for further applications. Producing and using these materials at the same construction site can help to reduce the cost and the duration of the construction. Up to 30% of cost savings could be achieved by in-place recycling of aggregate base materials (Edil 2011).



Figure 1. Recycled asphalt pavement (RAP) (Copeland 2011)



Figure 2. Recycled concrete aggregate (RCA) (Gonzalez and Moo-Young 2004)

Index Properties of RAP and RCA

Material characteristics such as morphology, gradation, angularity, and texture are different for each aggregate material (Tumiller 2013). The index properties of RAP and RCA are highly affected by several factors such as the material source, the aggregate type, and the crushing operations. RAP and RCA can contain a variety of impurities such as steel, metal, and tree residual which affect their index properties. The amount of the impurities is not constant and is affected by the original material source and crushing methods (Jyakyody et al. 2013).



TECH TRANSFER "STATE OF PRACTICE" REPORT

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Develop Collaborate Research Implement

Determining Pavement Design Criteria for Large Stone Subbase Materials

Introduction

The main working mechanism of pavements is distributing the traffic and vehicle loads to the sub-layers. The quality of base, subbase, and subgrade layers underlying a surface course are significant for the long-term pavement performance (Little and Nair 2009). Subbase course (Figure 1) is generally the second main load carrying layer after the base course. It is an optional layer and it is used to increase the efficiency of load distribution (Hoppe et al. 2015) and to separate base and subgrade layers. They are constructed to create a working platform over weak and soft subgrade layers (Schuettpelz et al. 2010) and to eliminate water mitigation by capillary action (Zornberg 2012). In general, relatively lower-quality aggregates than base layer aggregates are used (Zornberg 2012). In addition, relatively more rounded particles than base course aggregates can be used (Perkins et al. 2005).



Figure 1. The general structure of rigid and flexible pavements

Subgrade layers of pavements should be strong and stable enough to withstand the loads and to increase the service life of pavements (Kazeme et al. 2016). Due to fast-heavy and heavy weakening morphology of fine-grained subgrade layers, coarse-grained aggregate (Figure 2) layers are constructed to minimize the instability caused by subgrade and to protect the upper layers (surface and base course). Coarse-grained structure of aggregates minimizes the capillary action and help to evacuate the water coming from top layers easily (Uhlirmyer et al. 2003).

Large Stone Subbase Materials

The applications of large stone subbase (LSSB) materials as subbase layers and working platforms have been investigated by Idaho DOT, Illinois DOT, and Wisconsin DOT (Uhlirmyer et al. 2003; Kazeme et al. 2015; Kazeme et al. 2016). To improve the sustainability of pavement systems, the use of alternative materials such as LSSB materials (generally top size ≥ 75 mm or 3 in.) has been becoming popular. Large stones generally go through a single crushing operation. Thus, the amount of energy consumed to break up large aggregates to obtain conventional aggregate gradations for subbase applications can be reduced by using LSSB-type of materials (Kazeme et al. 2015).



Figure 2. Fine- to coarse-grained aggregates (left to right) (http://engineeringfeed.com/8-factors-affect-workability-fresh-concrete)

Index and Engineering Properties of LSSB Materials

Due to their large-sizes and the limitations of the test equipment and laboratory facilities, the LSSB materials cannot be tested easily in the laboratory. However, several field observations have been made. Thus, a limited information is available in the literature regarding their index and engineering properties (Kazeme and Tumiller 2015).

Grain and Gradation Characteristics

Since it is not practicable to sieve the large-size aggregates (e.g., LSSB) due to the limitations of the standard sieve sizes, high-resolution image techniques can be performed to obtain their particle size distribution (Kazeme and Tumiller 2015). In addition, several other morphological properties such as the flat and elongated particles, the angularity of particles can be observed by imaging techniques. The angularity of aggregates increases as the crushing operations goes from the primary stage to further stages. In general, the large-size aggregates may have less angularity compared to conventional aggregates because they generally go through a single crushing operation (Kazeme et al. 2016).

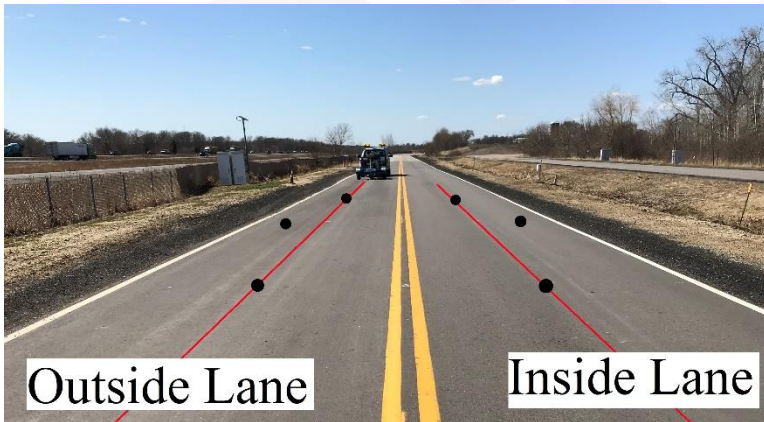
FIELD TESTING

- Field Trip – 04.26.2018
 - FWD
 - LWD



FIELD TESTING

CELL	STA	TP #	OUTSIDE LANE (+)			INSIDE LANE (-)		
			OWP	MID	IWP	IWP	MID	OWP
185 Coarse RCA	16379.00	1	o					o
	16409.00	2		o			o	
	16439.00	3	o					o
	16469.00	4		o			o	
	16499.00	5	o					o
	16529.00	6		o			o	
	16559.00	7	o					o
186 Fine RCA	16630.00	1	o					o
	16660.00	2		o			o	
	16690.00	3	o					o
	16720.00	4		o			o	
	16750.00	5	o					o
	16780.00	6		o			o	
	16810.00	7	o					o
188 Limestone	17057.00	1	o					o
	17087.00	2		o			o	
	17117.00	3	o					o
	17147.00	4		o			o	
	17177.00	5	o					o
	17207.00	6		o			o	
	17237.00	7	o					o
189 RCA+RAP	17308.00	1	o					o
	17338.00	2		o			o	
	17368.00	3	o					o
	17398.00	4		o			o	
	17428.00	5	o					o
	17458.00	6		o			o	
	17488.00	7	o					o



CELL	STA	TP #	OUTSIDE LANE (+)			INSIDE LANE (-)		
			OWP	MID	IWP	IWP	MID	OWP
127 18" LSSB	17506.00	1	o					o
	17536.00	2		o			o	
	17566.00	3	o					o
	17596.00	4		o			o	
	17626.00	5	o					o
	17656.00	6		o			o	
	17686.00	7	o					o
	17716.00	8		o			o	
	17746.00	9	o					o
227 18" LSSB	17815.00	1	o					o
	17845.00	2		o			o	
	17875.00	3	o					o
	17905.00	4		o			o	
	17935.00	5	o					o
	17965.00	6		o			o	
	17995.00	7	o					o
	18025.00	8		o			o	
	18055.00	9	o					o
328 9" LSSB Grid1	18079.50	1	o					o
	18099.50	2		o			o	
	18119.50	3	o					o
	18139.50	4		o			o	
	18159.50	5	o					o
428 9" LSSB Grid1+Fabric	18188.50	1	o					o
	18208.50	2		o			o	
	18228.50	3	o					o
	18248.50	4		o			o	
	18268.50	5	o					o
528 9" LSSB Grid2+Fabric	18297.00	1	o					o
	18317.00	2		o			o	
	18337.00	3	o					o
	18357.00	4		o			o	
	18377.00	5	o					o
628 9" LSSB Grid2	18407.50	1	o					o
	18427.50	2		o			o	
	18447.50	3	o					o
	18467.50	4		o			o	
	18487.50	5	o					o
728 9" LSSB original	18519.50	1	o					o
	18539.50	2		o			o	
	18559.50	3	o					o
	18579.50	4		o			o	
	18599.50	5	o					o
	18619.50	6		o			o	

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	
Task 1																																		
Task 2																																		
Task 3																																		
Task 4																																		
Task 5																																		
Task 6																																		
Task 7																																		
Task 8																																		
Task 9																																		

Thank You!

QUESTIONS??

