Project Title: Improve Material Inputs into Mechanistic Design Properties for Reclaimed HMA & RCA Roadways (Contract 1035212)

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April 29, 2020

Summary Report for Q1 for 2020

Use of recycled materials promotes sustainability in roadway construction by reducing consumption of energy and emission of greenhouse gases associated with mining and production of natural aggregates (Lee et al. 2011, Lee et al. 2013). Recycled materials often manifest mechanical behavior that is distinct from that of natural aggregate due to the composition and the nature of particulate characteristics. The most widely used recycled materials in roadway construction are recycled asphalt pavement (RAP) and recycled concrete aggregate (RCA) (Edil et al. 2012). The performance of a pavement system mostly depends on stiffness of the pavement structure under specified traffic loads and environmental conditions. RAP and RCA have comparable stiffness to natural aggregates that are currently used in roadway base course applications (FHWA, 2008; Guthrie et al., 2007). Hence, their use should be evaluated based upon their relative cost and stiffness properties.

In order to determine the mechanical behavior of the base and subbase layers in highway applications constructed with the recycled materials such as RAP and RCA a database was established. For this purpose, approximately 30 different reports/journal articles/conference proceedings were examined. The RCA and RAP materials for the available data was captured from the states of Minnesota, Colorado, Michigan, California, Texas, Ohio, New Jersey, Wisconsin, Illinois, Montana, Virginia, Florida, Tennessee, Maryland, New Mexico, Washington, Utah and Rhode Island. The laboratory data of more than 40 different recycled samples were collected in terms of mechanical properties. Most of the samples used in the studies were 100% recycled materials. However, there were also some recycled aggregate materials that were blended with natural aggregates at different mixture ratios.

The first material characteristics for the database were selected as the index properties which mainly consist of the gradation and Atterberg limit properties of the samples. For the gradation characteristics, gravel, sand, silt and clay contents, grain size distribution curve, effective diameter sizes (D_{60}, D_{30} and D_{10}), and coefficient of uniformity (C_u) and coefficient of curvature (C_c) were selected. Even though most of the materials used in these studies were course grained, some of them showed some plasticity. With the factors mentioned above the classification of the materials could easily be determined. Approximately 190 different materials including blends were used in the gradation database.

Furthermore, the database for the mechanical properties of the materials used in these studies were established with the compaction characteristics, hydraulic conductivity test, California bearing ratio test, shear strength and the resilient modulus tests results.

Resilient modulus (M_r) plays an important role in pavement design so most of the studies reported M_r as a stiffness characteristic. Models used for calculating M_r and the summary resilient moduli (SM_R) were reported at a bulk stress of 208 kPa for base materials will be reported. There are a couple of papers emphasizing on permanent deformation rather than the M_r for the pavement design. More than 400 M_r data were collected from the studies investigating stiffness of RAP, RCA or blends at different conditions. These conditions include different temperatures, freeze-thaw cycles or moisture contents.

Compaction characteristics include optimum moisture content and maximum dry density of RAP, RCA or blends. All compaction characteristics are collected and will be reported.

Hydraulic conductivity is another important characteristic of base and subbase materials. 61 hydraulic conductivity data were collected so far. Overall results showed that hydraulic conductivity generally tends to increase with higher RAP percent.

Shear stress results consist of cohesion coefficient (c) and angle of friction (ϕ), These data were collected for almost 60 different materials. Overall results showed that shear stresses of materials decreased with an increase in RAP percent.

Unconfined compression strength (UCS) tests were not conducted on RAP or RCA alone frequently since they are unbound granular materials with relatively low fines content (<15%). California Bearing Ratio (CBR) data were collected for approximately 30 materials (both soaked and unsoaked).

The summary of the database is presented in Table 1. The values in Table 1 show the number of test results for the corresponding tests for each study. In addition, void ratio, density, mineralogy and angularity of these materials could be influential. Therefore, these data were also collected when they were available.

At the moment the Task 2 (Data collection) is almost completed. For the next step, the draft Task 2 report will be submitted to TAP for review.

Table 1 (The values inside the cells are number of data for each reference)

#	Loc	Type of material	Grain Size Distribution	Atterberg Limits	Compaction		Hydraulic Conductivity			Shear Strength		Resilient Modulus	R Value	CBR	
					Standard Energy	Modified Energy	Falling Head	Constant Head	Flex Wall	Shear Box	Triaxial			Unsoaked	Soaked
1	MN, MI, CO, CA, TX, OH, NJ, WI	Aggregate class 5	1		1		1					26			
		Blend (50%RCA 50% class5)	1		1		1					2			
		RAP	7		7		7					96			
		RCA	7		7		7					96			
		RPM	2		2		2					4			
2	IL	60%RCA+40%RAP	1								6	6			
		100% RAP	1		1							6		1	
3	CO	RAP	11	11	11		11					45	11		
4	MT	RAP CBC#1	3		3		3								
		RAP CBC#2	3		3		3								
		RAP CBC#3	3		3		3			24			48		
		RAP pitrun	3		3		3			24			48		
5	VA	RAP	4	5								21		16	
6	FL	RAP	3		3						3				
7	NJ	DGABC													
		RAP								3		18			
		RCA													
8	Mn	RAP	4		4							16			
9	TN	RAP	1		3							9			
10	MD	RAP	7		7		7								
11	VA	RAP	4	4	4							PD=11			
12	Mn	RAP	1		1							2			
		RCA	2		2							4			
13	NM	RAP	3		1							16			
14	MN	RAP			3							9			
15	FL	RAP										PD=3			3
16	FL	RAP				8								8	
17	WA	RAP				5		5				20			
18	TX	RAP	1		1							5			

19	MN	RAP										PD= 6			
20	WI	RAP	1		2							7			
21	WI	RPM	1		1							1		1	
22	MN	RPM	1		1							1		1	
23	WI	RPM	1	1	1							1			
24	CA, TX, NJ, MI, CO, MN	Rap	4		4										
		RCA	4		4										
25	MN	RAP					4				4				
		RCM	4				4				4				
26	MN	RAP	6	6	6							6			
27	UT	RAP	4	4	4										
28	RI	RAP	7		7							7			
Total			106	31	101	13	56	5		51	17	422	107	27	3