ILLINOIS HIGHWAY MATERIALS SUSTAINABILITY EFFORTS 2018

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TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. PRR 170	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle **ILLINOIS HIGHWAY MATERIALS SUSTAINABILITY EFFORTS 2018**		**5. Report Date** August 20, 2019 **6. Performing Organization Code** N/A
7. Author(s) Kelly Morse		**8. Performing Organization Report No.** PRR 170
9. Performing Organization Name and Address Illinois Center for Transportation Department of Civil and Environmental Engineering University of Illinois at Urbana-Champaign 205 North Mathews Avenue, MC-250 Urbana, IL 61801		**10. Work Unit No.** N/A **11. Contract or Grant No.**
12. Sponsoring Agency Name and Address Illinois Department of Transportation (SPR) Bureau of Research 126 East Ash Street Springfield, IL 62704		**13. Type of Report and Period Covered** Calendar Year 2018 **14. Sponsoring Agency Code**

15. Supplementary Notes - Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data represented in this report. The contents do not necessarily reflect the official views or policies of IDOT. This report does not constitute a standard, specification, or regulation at IDOT.

16. Abstract

The Illinois Department of Transportation (IDOT) continues to use a variety of reclaimed and recycled materials in highway construction. Recycled materials are used in highway construction to supplement aggregates, concrete, hot-mix asphalt (HMA), steel, and sealants, as well as for soil modification and pavement markings. This report summarizes the materials used in 2018, along with specific reporting on the use of shingles, efforts to reduce the carbon footprint, and efforts to achieve cost savings by using recycled materials, as required by Illinois Public Act 097-0314.

17. Key Words Reclaimed asphalt shingles (RAS), recycled materials, Illinois Public Act 097-0314, sustainability, reclaimed, recycled, reclaimed asphalt pavement (RAP), recycled concrete material (RCM), fly ash, hot-mix asphalt (HMA), concrete aggregate.	**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		33	N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

EXECUTIVE SUMMARY

The Illinois Department of Transportation (IDOT) continues to use a variety of reclaimed and recycled materials in highway construction. Recycled materials are used in highway construction to supplement aggregates, concrete, hot-mix asphalt (HMA), steel, and sealants, as well as for soil modification and pavement markings. This report summarizes the materials used in 2018, along with specific reporting on the use of shingles, efforts to reduce the carbon footprint, and efforts to achieve cost savings by using recycled materials, as required by Illinois Public Act 097-0314.

The recycled materials tracked by IDOT are summarized in four major groups: aggregate, HMA, concrete, and other. The aggregate group includes recycled concrete material (RCM) and reclaimed asphalt pavement (RAP) used as an aggregate in lieu of natural aggregates used as granular fill or as a replacement for natural aggregates in HMA. The HMA group includes slags used as friction aggregate, crumb rubber, RAP, and reclaimed asphalt shingles (RAS). The concrete group includes fly ash, ground granulated blast furnace slag, and microsilica used to replace cement or supplement the cement and provide specific properties to the final concrete product. The “other” category group includes by-product lime used for soil modification, glass beads used for pavement-marking retroreflectivity, and steel used for reinforcement in concrete.

In 2018, reclaimed and recycled materials totaling 995,343 tons were used in Illinois highways. This represents nearly a 456,332-ton or 31% reduction from 2017 quantities. Significant funding decreases and the portfolio of project types are the major factors influencing recycle levels. On a tons-per-mile basis, the amount of recycled materials used in 2018 decreased significantly from 2017 levels. In 2017 there were 1,813.46 tons/mile, compared to 1,168.18 tons/mile in 2018. The reduction in quantities and similar unit equivalent values to 2017, resulted in a total value of $40,848,962, a significant decrease of 21% from 2017.

The amount of RAS used in 2018 was 26,996 tons, which is another significant decrease of 37% from the 2017 use of 42,821 tons. A major factor that decreased the overall RAS usage was the decrease in the tons of HMA used from 2017 to 2018. IDOT experienced a 32% decrease from 4,686,419 tons of HMA in 2017 to 3,202,866 tons of HMA used in 2018. In addition, RAS used in District 1 decreased from 28,555 tons in 2017 to 17,828 tons in 2018, or a 38% decrease. The number of paving projects, lane miles, and types of mixes used heavily influences the amount of RAS used each year. The number of IDOT districts for which contractors produced HMA containing RAS dropped to six in 2018, which also lowered the overall use of RAS.

The amount of reclaimed asphalt pavement (RAP) used for HMA decreased from 801,776 tons in 2017 to 638,298 tons in 2018, or a 20% decrease.

While reporting tons of materials is an easy measure, it does not represent the true environmental benefit of recycling the various materials. This report estimates the equivalent carbon dioxide (CO_2EQ) emissions savings of the recycled materials used by IDOT. The use of fly ash resulted in the greatest environmental benefit by replacement of energy-intensive cement. It is estimated that IDOT’s recycling efforts reduced CO_2EQ emissions 80,764 tons in 2018. The use of fly ash accounted for approximately 42% of the reduction in emissions documented herein.

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CHAPTER 1: INTRODUCTION

This report is part of a series of annual reports published since 2010 to document recycling and sustainability efforts of the Illinois Department of Transportation (IDOT). This report also meets the reporting requirements of Illinois Public Act 097-0314 (Illinois General Assembly 2012).

Various past reports by IDOT and the Illinois Center for Transportation (ICT) provide excellent background information on reclaimed and recycled materials used in highway construction (Brownlee 2011, 2012; Brownlee and Burgdorfer 2011; Griffiths and Krstulovich 2002; IDOT 2013; Lippert and Brownlee 2012; Lippert et al. 2014, 2015, 2016, 2017; Rowden 2013; Morse 2018).

In 2012, Illinois Public Act 097-0314 called on IDOT to report annually on efforts to reduce its carbon footprint and achieve cost savings through use of recycled materials in asphalt paving projects (IDOT 2013; Lippert and Brownlee 2012; Rowden 2013; Morse 2018). The act also required IDOT to allow the use of reclaimed asphalt shingles (RAS) in all hot-mix asphalt (HMA) mixes only if such use does not cause negative impacts to pavement life-cycle cost.

Illinois has many years of experience using various reclaimed materials in highway construction. These materials tend to be materials that reduce the use of virgin materials such as aggregate, cement, or asphalt. Fly ash and ground granulated blast furnace slag (GGBFS) have been added to concrete in Illinois for over 50 years. These additions reduce the amount of cement (a carbon-intensive material) required, while also lending other desirable properties to concrete. Reclaimed asphalt pavement (RAP) has been in use since the early 1980s, and its use is widely accepted.

Other materials, such as RAS, have a much shorter history of use. Until 2011, IDOT was conducting experimental projects using RAS in HMA. With the passage of Public Act 097-0314, specifications were developed and adopted to allow use of RAS on all IDOT projects as a contractor option (Lippert and Brownlee 2012). As with the adoption of any new specification or policy, issues and areas of improvement were identified and changes implemented. Earlier versions of this report documented the resulting changes and improvements.

This report is structured with each chapter covering various aspects of the use of reclaimed and recycled materials. Chapter 2 presents IDOT's overall use of reclaimed and recycled materials in highway construction projects. Chapter 3 provides a specific look at IDOT's efforts in utilizing RAS in HMA paving. Chapter 4 presents a life-cycle assessment based on available information which portrays the environmental benefits of recycling the various materials. Chapter 5 provides an overview of research projects that will provide long-term improvements to the life-cycle of pavements using recycled materials.

CHAPTER 2: USE OF RECLAIMED AND RECYCLED MATERIALS IN ILLINOIS HIGHWAY CONSTRUCTION IN 2018

2.1 REPORTING HISTORY

The first recycling report was published in 2002 to answer various inquiries on recycling (Griffiths and Krstulovich 2002). After that first effort to report on recycled materials, a follow-up report was not produced until construction information was available in 2010 (Brownlee and Burgdorfer 2011). Reporting of recycled material use has since been on an annual basis (Brownlee 2011, 2012; Lippert et al. 2014; Rowden 2013). The 2012 report on use of recycled materials provided the most in-depth overview of how each material is derived and used in highway construction (Rowden 2013). The 2013, 2014, 2015, 2016 and 2017 reports provided benchmark performance measures on recycled material use on a per-mile basis rather than total quantity (Lippert et al. 2014, 2015, 2016, 2017; Morse 2018).

This report uses the same basic methodology for determining quantities as used in past reports from IDOT's Materials Integrated System for Test Information and Communication (MISTIC). Information from MISTIC is summarized to report quantities of each recycled material. The data reporting followed the same data collection methodology from the 2013 report on use (Lippert et al. 2014). Beginning with the 2016 sustainability report, the RAS data collection methodology was modified from a contactor survey on use to reliance on data contained in MISTIC (Lippert et al. 2017).

2.2 RECLAIMED AND RECYCLED MATERIALS ADDED OR DELETED IN 2018

The list of reclaimed and recycled materials used by IDOT was reviewed while preparing this report. During the 2018 reporting year, no new materials were added, or old materials deleted.

2.3 MATERIALS RECLAIMED AND RECYCLED IN 2018

2.3.1 Determining Recycle Quantities

The quantities presented in this report pertain to the materials for which the amount of recycled material can be soundly documented through existing records. Items such as steel reinforcement and glass beads are composed of 100% recycled materials, by means of how those materials are manufactured, and thus are simple to report. Many additional tons of recycled materials are used, but tracking quantities used is impractical. For example, recycled steel is used in large steel shapes for bridge construction; however, the amount of recycled material varies in each steel heat or batch. Information on the recycled content of such items is not available in the database and therefore not reported.

While MISTIC reports are the source of material quantities for most of the reported materials, there is an exception—namely, glass beads. The reported quantity for glass beads is based on quantities accepted for use in the state of Illinois. This quantity includes use by some local agencies that take part in statewide purchase agreements.

Previous versions of this report determined RAS quantities via a contractor survey. The reason this method of data collection was done was that MISTIC reporting of RAS quantities needed to be developed and shown to be reliable. Improvements in MISTIC documentation and reporting have progressed to the point that there is no longer a need to survey contractors for RAS quantities.

2.3.2 Economic Values of Recycled Materials

Economic values for the various materials were updated to provide a reasonable comparison from year to year. For 2018 pricing, a statewide average was determined from supplier- and contractor-provided information. For items that have price indexes, such as steel, the monthly IDOT index was averaged for the year (IDOT 2018b).

2.3.3 Recycled and Reclaimed Material Use and Values for 2018

2.3.3.1 Data for 2018

Appendix A presents the 2018 recycled and reclaimed material quantities and values. In total, 995,343 tons of recycled material were used in 2018, which is a 31% decrease in recycled tonnage from the 1,451,675 tons in 2017. The value of 2018 recycled materials were $40,848,962, a 21% decrease from $51,488,535 in 2017. In 2018, the miles of roadway improvement increased, the number of bridges constructed or rehabilitated decreased, and value of projects awarded was higher, as compared with 2017 figures. Despite the increase in miles of roadway improvements, the recycled tonnage in 2018 decreased significantly. This is greatly due to type and scope of projects constructed. The increased use of pavement preservation treatments, that currently do allow recycled materials (such as crushed slag, crushed steel slag and crushed concrete), are believed to be a potential source of the discrepancy between the increase in lane miles yet decrease in the use of recycled materials. These treatments are constructed much thinner than traditional pavements and thus significantly lower volumes of materials are needed to construct a lane mile. Therefore, less material used per lane mile equals less recycled material used to construct a lane mile. In addition, the quantity of recycled materials used to construct these treatments is not documented in MISTIC and therefore is not accounted for in the data used to compile this report.

2.3.3.2 Data Analysis of 2018 Use

To present a more accurate picture of IDOT’s recycling effort, a series of figures is presented which provides information on 2018 results, as well as historical trends. As shown in Figure 1, the bulk of the recycled tonnage was made up of three materials: RAP in HMA, recycled concrete material (RCM), and RAP as an aggregate.

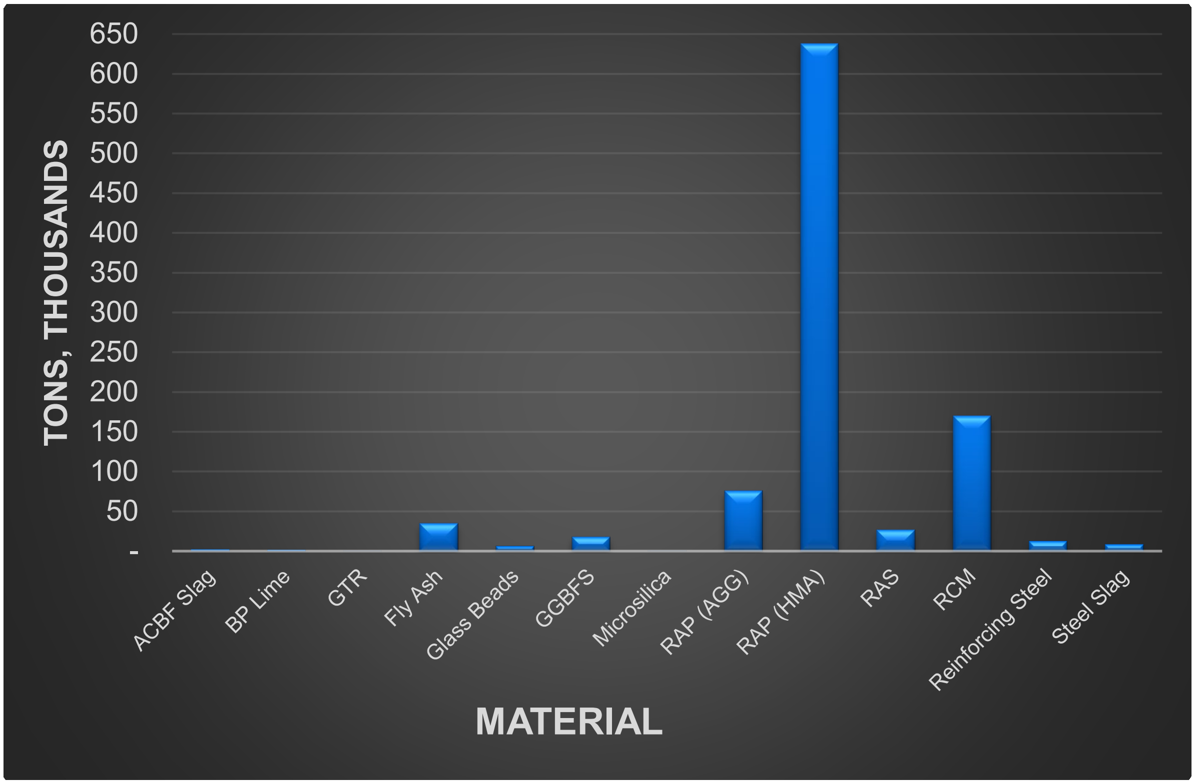

Figure 1. Reclaimed material used in 2018.

Figure 2 breaks out quantities by related uses for HMA, aggregate, Portland Cement Concrete (PCC), and other. The other category consists of by-product lime, glass beads, and steel. The HMA category includes slags used as friction aggregate (in HMA), crumb rubber, RAP, and RAS. PCC-related materials include fly ash, ground granulated blast furnace slag (GGBFS), and microsilica used to replace cement or provide specific properties to the final concrete product. Aggregate use consists of RCM and RAP used in lieu of natural aggregates. From this summary, recycled materials related to HMA and aggregate use represents the majority of IDOT recycled tonnage.

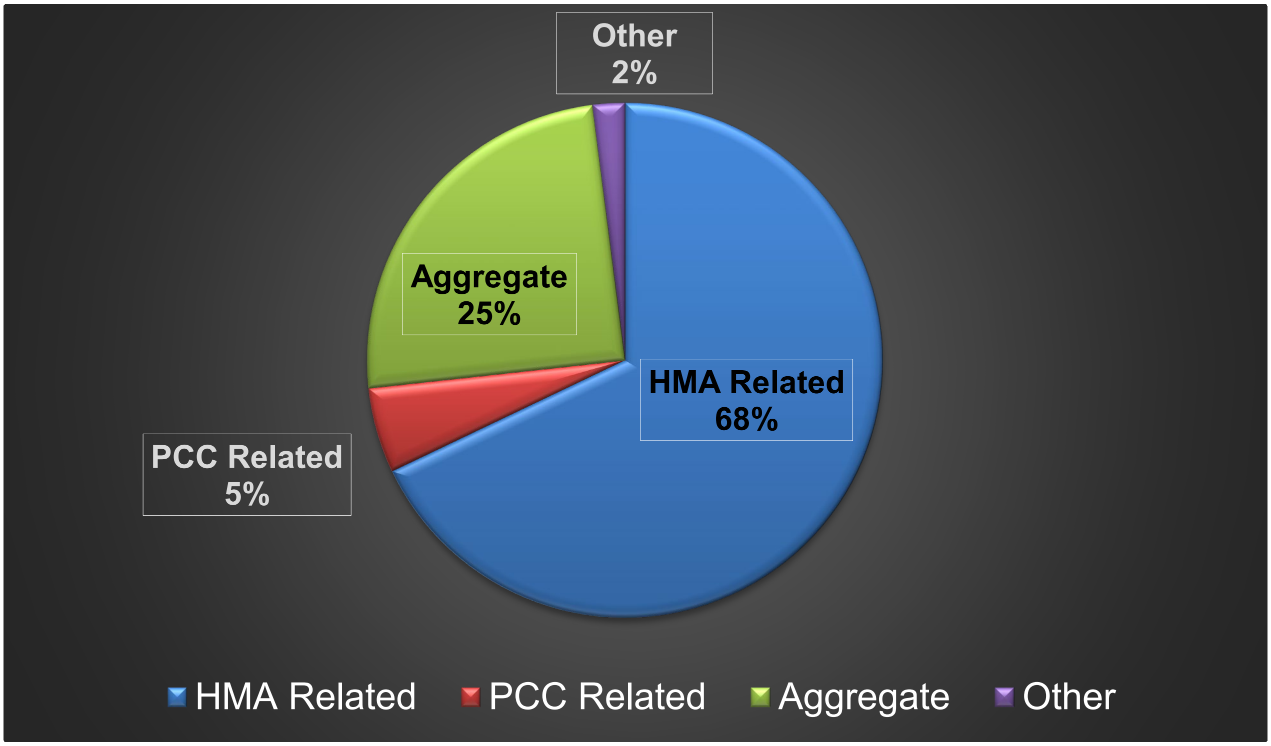

Figure 2. Reclaimed materials by related tons of use in 2018.

2.4 HISTORICAL RECYCLING TRENDS AND DATA ANALYSIS

2.4.1. Recycling Relationship to Program Budget

Recycling quantities are highly correlated to the overall budget and portfolio of project types (bridge vs. pavement resurfacing vs. reconstruction) within a budget year. In general, resurfacing projects result in RAP being both produced and used. Major reconstruction or new alignment (greenfield) projects can use substantial amounts of recycled material. By contrast, bridge projects tend to use limited amounts of materials because of the short lengths involved with these types of projects. The increased use of pavement preservation treatments, which currently do not allow recycled materials (other than limited quantities of steel slag), are influencing the 2018 recycling trends. Pavement preservation treatments are constructed much thinner than traditional pavements and thus require significantly lower volumes of materials, which then leads to even less recycled materials needed to construct a lane mile.

Presented in Figure 3 are the total tons recycled from calendar years 2010 through 2018.

Also presented in the chart by fiscal year (FY; IDOT’s FY is July 1 through June 30) are the values of projects awarded, centerline miles paved/improved, and number of bridges built/improved (IDOT 2018a). Note that this timeframe is not the same as the calendar year (CY) reported for recycled tonnage. However, the values tend to align themselves roughly on a CY basis because of the delay between the award of contracts and the use of materials in the project. For this report, it was considered reasonable to use all data as if they had been from the same time-period by CY.

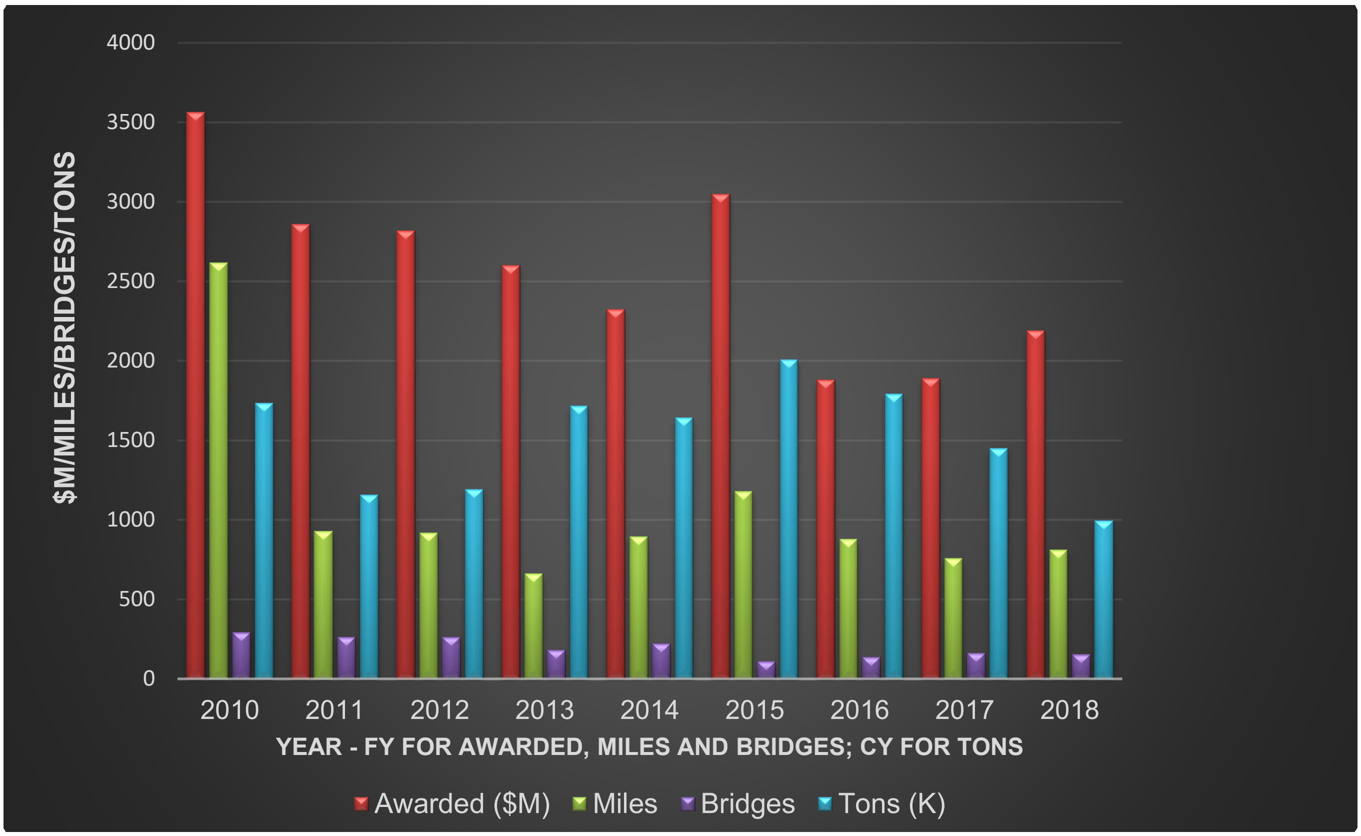

Figure 3. Annual projects awarded (FY), miles improved (FY), bridges built/improved (FY), and recycled tons (CY).

2.4.2 Determination of Recycled Content

To provide a more representative performance measurement of IDOT's recycling efforts, previous reports presented the general recycle content by calendar year (Lippert et al. 2014, 2015, 2016, 2017). That approach is continued in this report. Figure 4 represents the results of determining the average tons of recycled material for each centerline mile of improvement since 2010. On a tons-per-mile basis, 2018 represents an 31% decrease in recycle quantity from 2017.

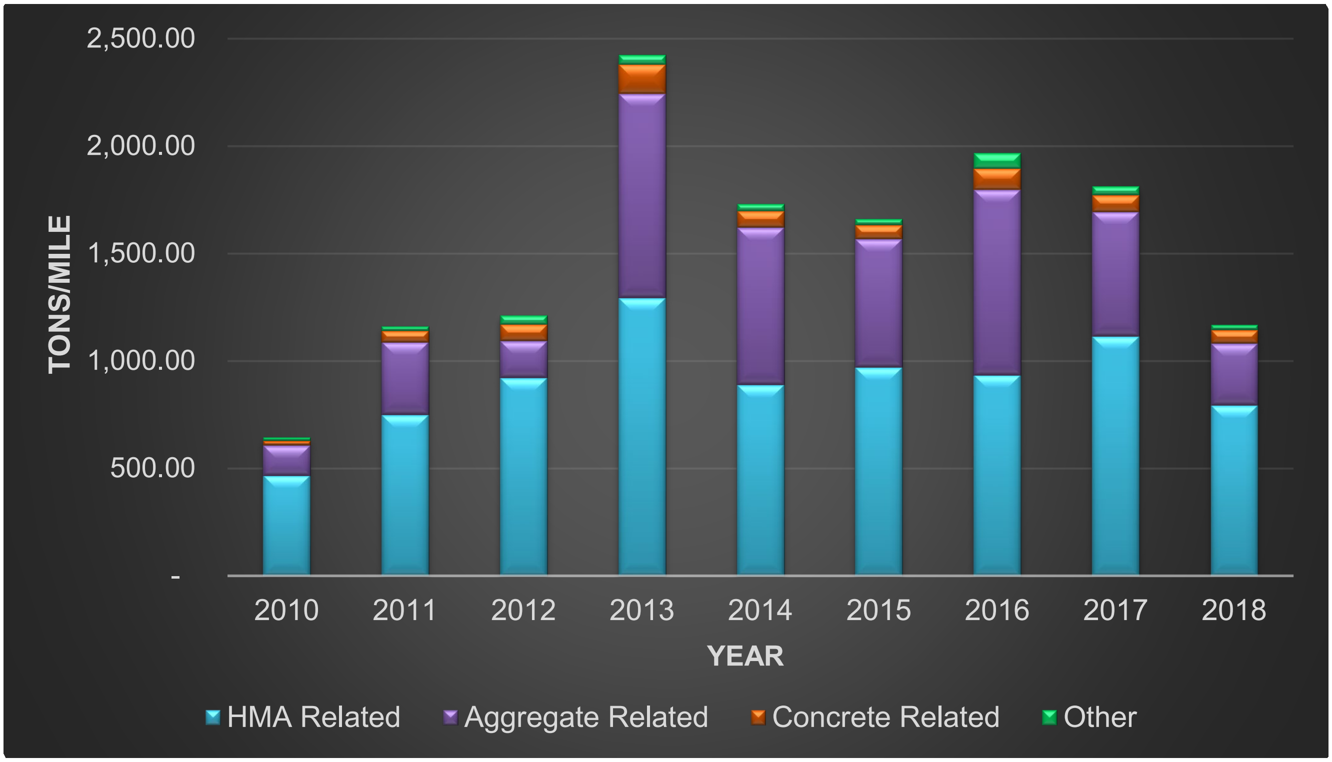

Figure 4. Historical recycle content.

2.5 REGIONAL/DISTRICT RECYCLING EFFORTS

District 1 developed their own special provision to use resources unique to their area. The previous report described the special provisions in effect at the time (Lippert et al. 2014, 2015, 2016, 2017). No changes, additions, or deletions were made to Regional/District special provisions in 2018.

CHAPTER 3: RECLAIMED ASPHALT SHINGLES

This chapter is a continuation of reporting on the specific status and use of RAS as required by Illinois Public Act 097-0314 (Illinois General Assembly 2012). Several reports provided details of RAS adoption (IDOT 2013; Lippert and Brownlee 2012; Lippert et al. 2014, 2015, 2016, 2017). MISTIC data were used to report 2018 RAS usage.

3.1 RAS POLICIES AND SPECIFICATIONS IN EFFECT FOR 2018

3.1.1 RAS Policy for Sources

The Central Bureau of Materials (CBM) Policy Memorandum, "Reclaimed Asphalt Shingle (RAS) Sources" (28-10.3), continued to be in effect for all 2018 RAS production and represents no change in policy since 2012. The policy can be found in the report on RAS use in 2012 (IDOT 2013). During 2018, IDOT added new RAS suppliers, with a total of 23 (IDOT 2018).

3.1.2 RAS Specifications

3.1.2.1 Statewide Specifications

The Bureau of Design and Environment (BDE) specification, "Reclaimed Asphalt Pavement and Reclaimed Asphalt Shingles (BDE)," was revised with an effective date of January 1, 2019. A copy of that special provision is included in Appendix B.

3.1.2.2 Regional/District Specifications

The District 1 Special Provisions did not change for 2018.

3.2 QUANTITY OF RAS USED IN CALENDAR YEAR 2018

In 2018, IDOT experienced a decrease in RAS use. The total used in 2018 was 26,996 tons which was a 37% decrease from 2017 at 42,820 tons. A major factor that decreased the overall RAS usage was the decrease in the tons of HMA used from 2017 to 2018. IDOT experienced a 32% decrease from 4,686,419 tons of HMA in 2017 to 3,202,866 tons of HMA used in 2018. The decrease can also be attributed to a significant decrease in RAS usage by District 1 from 28,555 tons in 2017 to 17,828 tons in 2018 as well as no use of RAS in 3 Districts.

In 2018, six of the districts reported use of RAS, which is down one district from the previous year. The map in Figure 5 provides the percentage of the 2018 statewide total RAS used by each IDOT district. The graph in Figure 5 shows the percentages used in each district relative to the total used statewide.

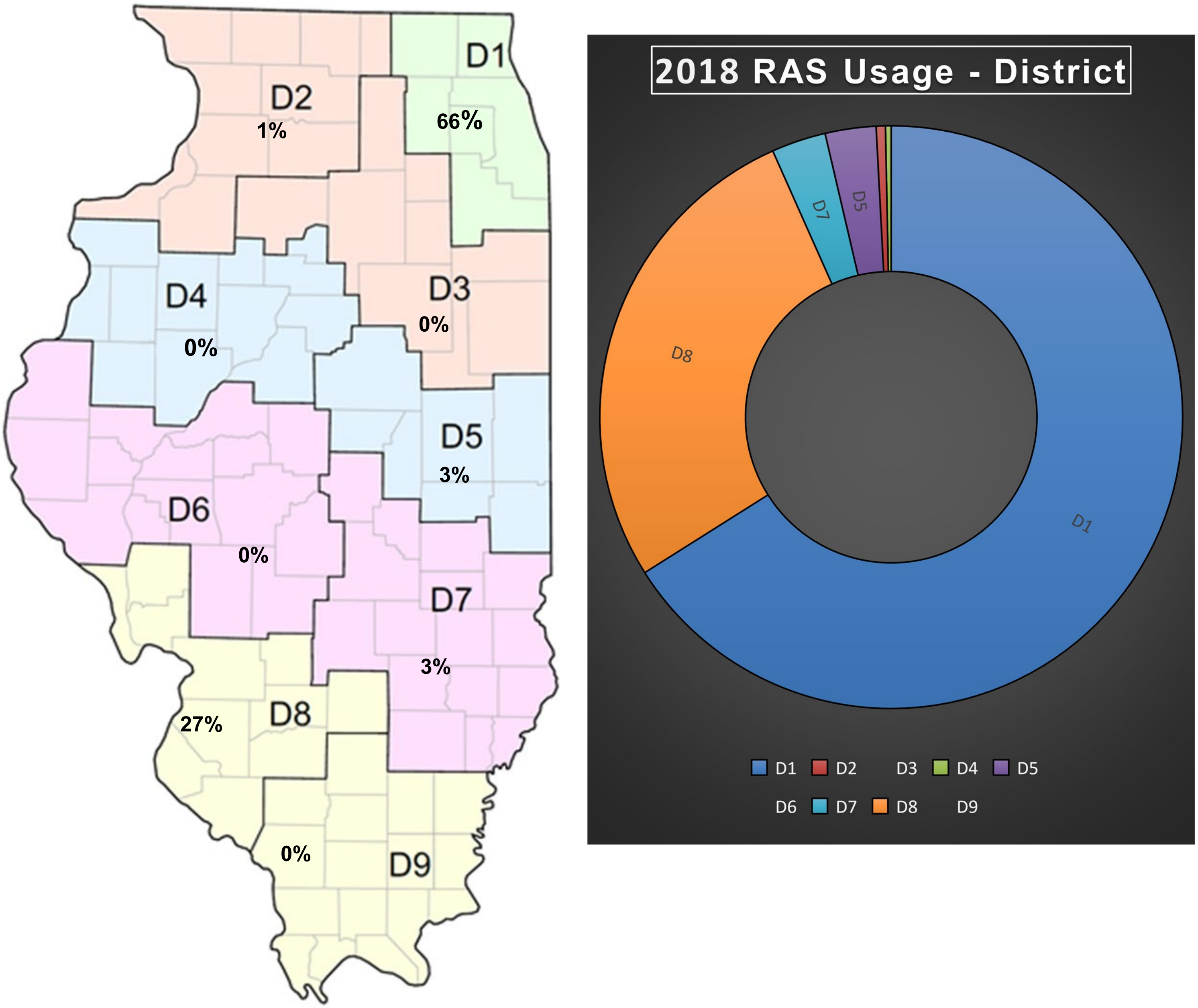

Figure 5. Percentage of RAS used by each district in calendar year 2018.

CHAPTER 4: ENVIRONMENTAL EVALUATION OF RECYCLED MATERIALS USED IN 2018

Over the years, the prime driver for use of recycled materials has been the initial cost savings of using reclaimed materials. Often these materials have a low economical value due to the need to remove or dispose of them from the site of generation. Often these materials can be used to replace more costly virgin materials, provided they are produced to a consistent quality standard. The ability to fully or partially replace virgin and/or manufactured materials with a product that otherwise would be landfilled or stockpiled as a waste can also greatly reduce the environmental burden of highway materials. As such, this chapter provides a summary of quantitative analysis for using recycled materials in terms of carbon emissions.

4.1 LIFE-CYCLE ASSESSMENT

An approach used for evaluation of the environmental burden of processes in life-cycle assessment (LCA) can also be applied to pavements and paving materials. This approach estimates, based upon documented processes, all aspects of a material used for a given application from cradle to grave. As part of the LCA process, each step of material production is analyzed in detail to determine a common and simple environmental-burden measure. Typically, the measure used is carbon dioxide equivalents per ton of the material used, or CO_2EQ/ton.

For a simple example of aggregate production, fuel and electricity use can be assigned to each step. For virgin aggregate, the material must be mined, crushed, sized, transported to the site, placed, compacted, and used for the duration of the facility, then salvaged or wasted at the end of the facility's life. Recycled aggregates have an advantage in that they do not have the economic or environmental burden of mining, which is a major part of the environmental savings in recycled aggregate.

This report used LCA values from the literature for both virgin materials and recycled materials used in Illinois to estimate a CO_2EQ/ton for each material recycled and the virgin material being replaced. The difference in CO_2EQ/ton between virgin and recycled material is the "savings" noted in Table 1 for each material, in kilograms equivalent of CO_2 for each ton of material recycled, for which information was available (Chen et al. 2010; EarthShift 2013; Prusinski 2003; Sunthonpagasit and Duffey 2004; World Steel Association 2011). For 2018, the total CO_2EQ savings in tons is also presented. This estimate includes typical transportation distances for Illinois. A main assumption is that the performance of the highway infrastructure item is equivalent for both virgin and recycled options.

Materials that have low CO_2EQ, such as aggregates, have very low values of savings when recycled materials are used. By contrast, when energy-intensive materials such as lime and cement are replaced with by-products such as fly ash, by-product lime, or GGBFS, very high savings of CO_2EQ can be realized.

From this simple analysis, it is estimated that a total of 80,764 tons of CO_2EQ was saved in 2018. Appendix A presents an accounting of CO_2EQ saved in 2018 for each of the materials used. As noted previously, using total tons of recycled material alone is limited as a performance measure for recycling. The environmental burden saved by material for 2018 is presented in Figure 6. This picture is very different from the tons of material as presented in Figure 1. Likewise, Figure 7 shows the distribution of CO_2EQ savings by related use, which differs greatly from the tonnage distribution presented previously in Figure 2.

Table 1. Estimated Environmental-Burden Savings by Use of Recycled Material

Material	Savings per Ton of Use, CO_2EQ (kg)	2018 CO_2EQ Savings (Tons)
Air-Cooled Blast Furnace Slag	13	30
By-Product Lime	920	1,563
Crumb Rubber	1,704	35
Fly Ash	894	34,207
Glass Beads	929	6,113
Ground Granulated Blast Furnace Slag	763	15,398
Microsilica	NA	NA
Reclaimed Asphalt Pavement Used for Aggregate	0.8	67
Reclaimed Asphalt Pavement Used For HMA	17	11,961
Reclaimed Asphalt Shingles	79	2,351
Recycled Concrete Material	0.8	150
Steel Reinforcement	640	8,724
Steel Slag	17	163

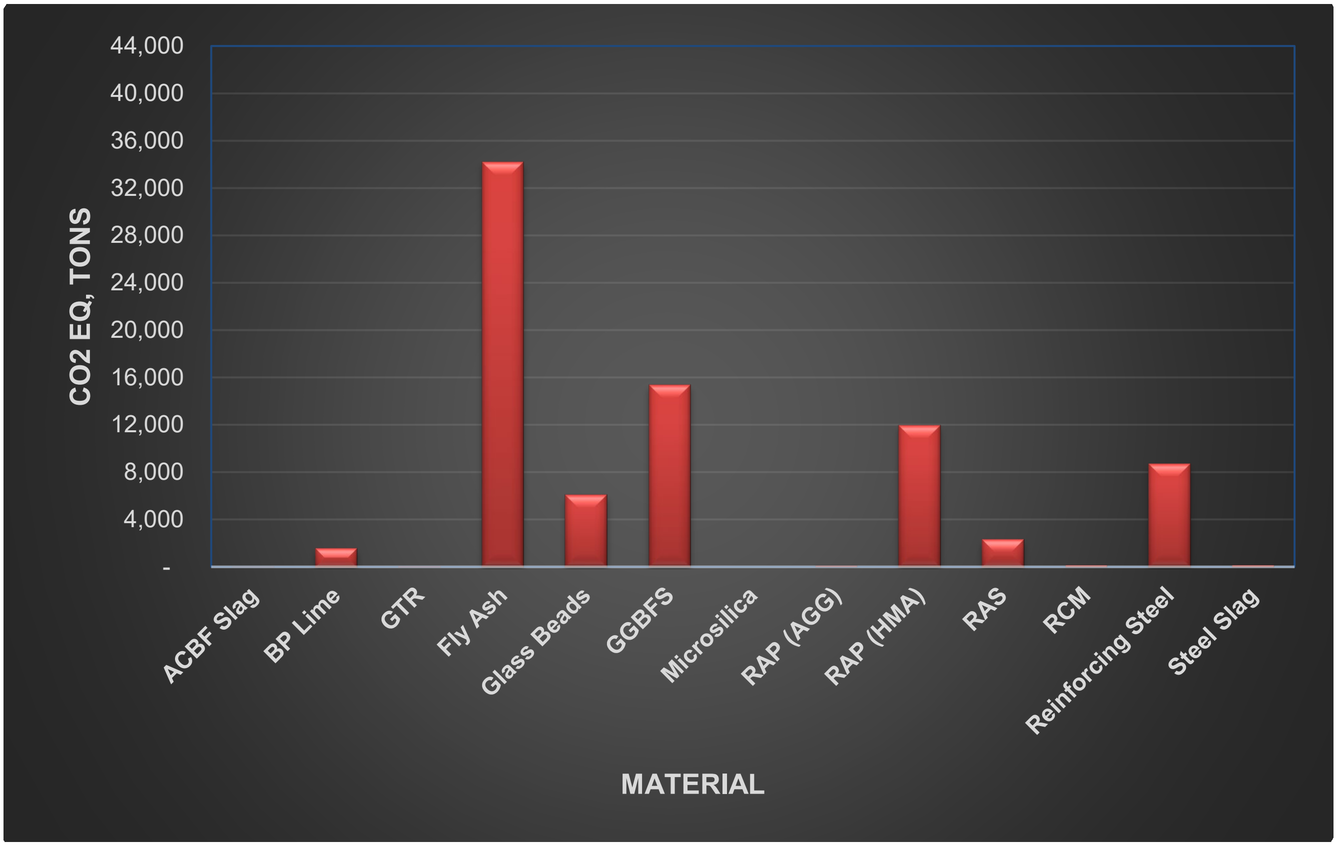

Figure 6. CO_2EQ saved, by material, in 2018.

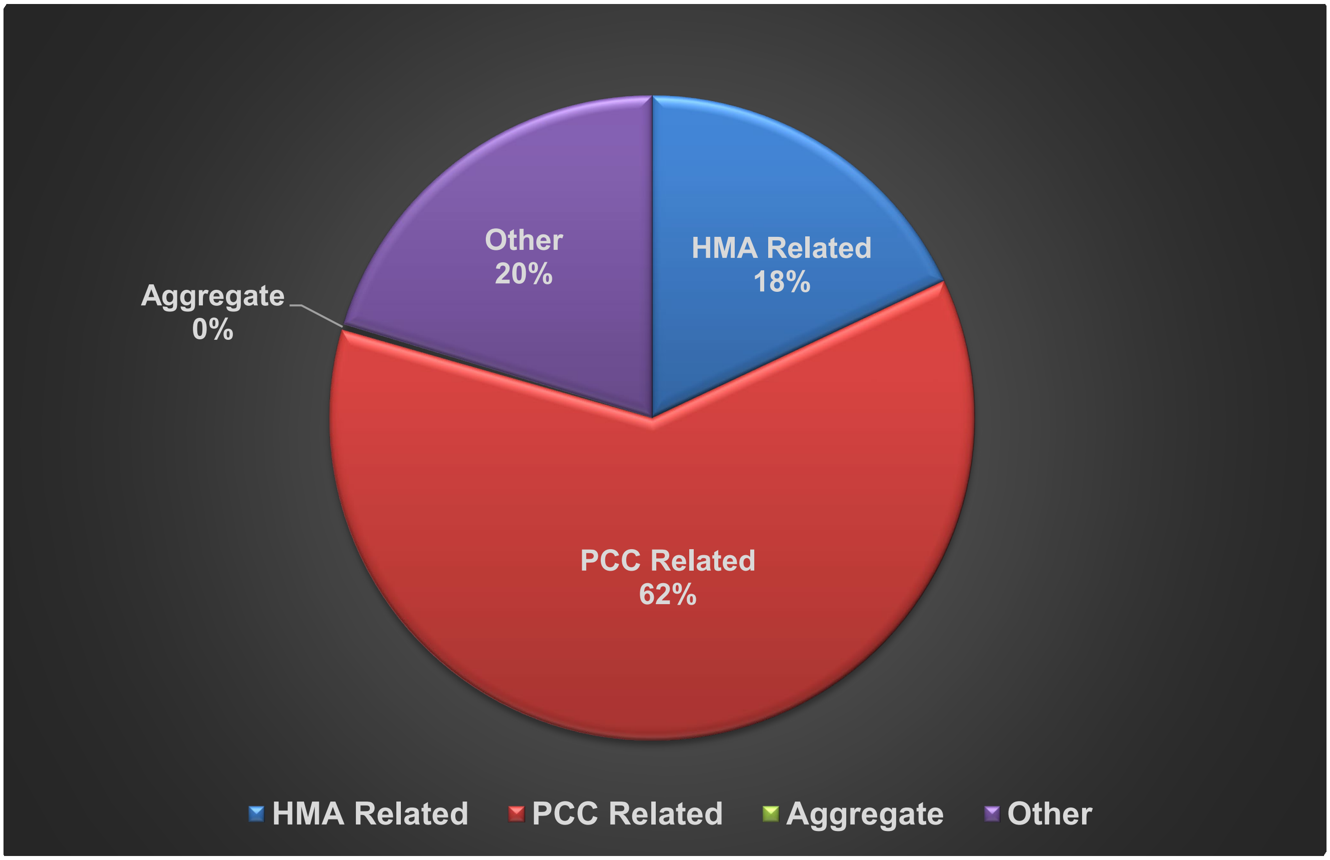

Figure 7. CO_2EQ saved, by related use, in 2018.

CHAPTER 5: SUSTAINABILITY-RESEARCH ACCOMPLISHMENTS AND INITATIVES

During 2018, IDOT had several sustainability-related studies underway with ICT. These efforts focused on the use of recycled materials. Each of these studies resulted in an interim or final report. A brief description of each effort is provided.

5.1 SUSTAINABILITY RESEARCH INITITATED AND ONGOING DURING 2018

5.1.1 R27-180 Concrete Pavement Mixtures with High Supplementary Cementitious Materials (SCM) Content

This project began in October 2017 and is scheduled to be completed in June 2021. The principal objectives of Phase I of this project are to first validate/calibrate existing fly ash compositional equations that predict properties of concrete materials for pavements and then extend and/or develop new characterization protocols for high SCM replacement rates of cement (fly ash and slag) available in the State of Illinois. The goal is to have simple characterization and testing protocols that will allow the use of high volume SCMs in concrete pavement without compromising workability, air content, initial setting time, early strength gain, long term mechanical properties, and durability. Phase II objectives will be focused on using the compositional characterization protocols to predict the fresh and mechanical properties and durability performance for concrete containing high SCMs applied to pavements.

5.1.2 R27-175 Development of Long-Term Aging Protocol for Implementation of the Illinois Flexibility Index Test (I-FIT)

This project began in January 2017 and will conclude in August 2019. Because of ICT project R27-128, the Illinois Flexibility Index Test (I-FIT) was developed to screen AC mixes' capacity for cracking resistance. This test method evaluates AC mixes at 25 °C and at a loading head displacement rate of 50 mm/min. The flexibility index (FI), derived from the I-FIT results, is a simple index parameter correlated to fundamental crack growth mechanisms in the process zone. The parameter can distinguish mixes with varying characteristics that may result in different cracking resistance capacities. A provisional AASHTO test specification was prepared and accepted by the relevant AASHTO subcommittee as TP-124. Integration of the I-FIT method into IDOT's AC mix design specifications is underway. Several steps are required to complete the implementation. Therefore, the following research objectives are identified as follows: (1) Development of Long-Term Aging Protocol with specification criteria, and (2) Development of thresholds for long-term aged plant and laboratory produced mixtures.

5.1.3 R27-168 Field Performance Evaluations of Sustainable Aggregate By-Product Applications (Phase II)

This project began in September 2015 and concluded in September 2018. In its last year, this study was intended to determine from field performance evaluations the most successful sustainable/green applications utilizing large quantities of quarry by-product fines (QB) in road construction. Full-scale test sections were constructed to demonstrate innovative and sustainable uses of QB applications. The constructed pavement sections were tested using the University of Illinois's accelerated pavement-testing equipment to evaluate field performances of the most promising QB applications. The study lead to draft specifications for beneficial QB utilization, which is expected to have an immediate impact on sustainable construction practices in the state of Illinois by reducing total energy consumption and greenhouse gas emissions per ton of aggregate production and resulting in significant savings on IDOT construction projects. By utilizing an optimized quantity of QB in soil modification, thus lowering the quantity of lime and or cement required to meet soil modification requirements for subbase, the environmental impacts of construction are greatly reduced.

5.1.4 R27-196HS Rheology-Chemical Based Procedure to Evaluate Additives/Modifiers used in Asphalt Binders for Performance Enhancements (Phase 2)

This project started July 2018 and will conclude December 2020. The overall goal of the project will be to develop an advanced and systematic binder screening protocol that includes a long-term aging procedure for modified binders with rheological and chemical characterization methods. At the end of the proposed study, it is also expected that preliminary thresholds established in project ICT R27-162 will be validated and fine-tuned based on various combinations of rheology-chemistry space diagrams.

5.1.5 R27-193-1 Flexible Pavement Recycling Techniques

This project began in July 2018 and will conclude in July 2021. The objective of this project is to further develop and refine specifications, procedures, and policies for flexible pavement recycling techniques (Cold Central Plant Recycling and Full-Depth Reclamation with Cement).

5.1.6 R27-193-2 Flexible Pavement Design (Full-Depth and Rubblization)

This project began in July 2018 and will conclude in July 2021. Project activities will focus on utilizing BDAT (Best Demonstrated Available Technology) as related to Full-Depth HMA pavements and Rubblized Portland Cement Concrete Pavement with HMA Overlay.

CHAPTER 6: CONCLUSIONS

The goal of this report is to provide a single-source document for 2018 sustainability efforts in highway materials that serves to meet the reporting requirement of Illinois Public Act 097-0314. In summary, the 2018 efforts in recycling resulted in the following:

- In 2018, recycled materials used in highway projects totaled 995,343 tons, with a value of $40,848,962.
- Usage of reclaimed asphalt shingles (RAS) in 2018 decreased 37% from 2017 levels. A major factor that decreased the overall RAS usage was the decrease in the tons of HMA used from 2017 to 2018. IDOT experienced a 32% decrease from 4,686,419 tons of HMA in 2017 to 3,202,866 tons of HMA used in 2018. The decrease may also be attributed to the significant decrease, 38%, in RAS use by District 1 from 28,555 tons in 2017 to 17,828 tons in 2018. Reclaimed asphalt pavement (RAP) used for HMA decreased from 801,776 tons in 2017 to 638,298 tons in 2018, or a 20% decrease.
- Using Life-cycle assessment (LCA) and available information, it is estimated that carbon dioxide–equivalent emissions were reduced by 80,764 tons in 2018. The major contribution to the reduction was the use of fly ash to replace cement at a reduction of 34,207 tons. Also, the use of Ground Granulated Blast Furnace Slag and RAP for HMA reduced by over 25,000 tons combined.
- With respect to material sustainability research projects in 2018, the department had six projects active or ongoing in 2018, with another two projects starting in 2018. These research projects will result in a total of at least eight publications in the form of interim/final reports and white papers.

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APPENDIX A: RECYCLED AND RECLAIMED MATERIALS: QUANTITIES USED AND EQUIVALENT VALUES, 2018

Material	Unit Equivalent Value	Quantity[1] Tons	Total Equivalent Value to Department	CO_2 Equivalent Savings Tons[6]
Air-cooled blast furnace slag	$16.00	2,117	$33,872	30
By-product lime	$35.00	1,541	$53,935	1,563
Crumb rubber[2]	$400.00	18.9	$7,552	35
Fly ash	$20.00	34,712	$694,240	34,207
Glass beads[3]	$596.000	5,970	$3,557,941	6,113
Ground granulated blast furnace slag	$85.00	18,308.0	$1,556,180	15,398
Microsilica	$500.00	114	$57,000	-
Reclaimed asphalt pavement used for Aggregate	$11.00	75,849	$834,339	67
Reclaimed asphalt pavement used for HMA	$25.00	638,298	$17,825,962	11,961
Reclaimed asphalt shingles	$35.00	26,997	$944,895	2,351
Recycled concrete material	$12.00	170,359	$2,044,308	150
Steel reinforcement[4]	$1,056.47	12,367	$13,064,878	8,724
Steel slag	$20.00	8,693	$173,860	163
Wet-bottom boiler slag[5]	NA	NA	NA	NA
Totals	**—**	**995,343**	**$40,848,962**	**80,764**

[1] Quantities were calculated from amounts assigned to projects in calendar year 2018. Prior to summation of values, metric values were converted to English values using factors located in Appendix B of the *Standard Specifications for Road and Bridge Construction.*
[2] Crumb rubber: This material quantity was calculated as 5% of the quantity of hot-poured joint sealant used in 2018.
[3] Glass beads use is based on tested and approved quantities and not projects assigned through MISTIC.
[4] Steel reinforcement: For this report, the IDOT monthly steel index was averaged for 2018 and used to represent the value of just the steel contained in these products. This approach does not include the epoxy coating value in the calculation of the material being recycled, which is a more accurate representation.
[5] Wet-bottom boiler slag: No records were found in MISTIC that indicated WBBS was used for any IDOT projects in 2018.
[6] Based on typical haul distances for Illinois and industrial averages between virgin material and recycled/reclaimed material found in the literature.

APPENDIX B: RECLAIMED ASPHALT PAVEMENT AND RECLAIMED ASPHALT SHINGLES, JANUARY 1, 2018

"**SECTION 1031. RECLAIMED ASPHALT PAVEMENT AND RECLAIMED ASPHALT SHINGLES**

1031.01 Description. Reclaimed asphalt pavement and reclaimed asphalt shingles shall be according to the following.

(a) Reclaimed Asphalt Pavement (RAP). RAP is the material produced by cold milling or crushing an existing hot-mix asphalt (HMA) pavement. The Contractor shall supply written documentation that the RAP originated from routes or airfields under federal, state, or local agency jurisdiction.

(b) Reclaimed Asphalt Shingles (RAS). Reclaimed asphalt shingles (RAS). RAS is from the processing and grinding of preconsumer or post-consumer shingles. RAS shall be a clean and uniform material with a maximum of 0.5 percent unacceptable material, as defined in Central Bureau of Materials Policy Memorandum, "Reclaimed Asphalt Shingle (RAS) Sources", by weight of RAS. All RAS used shall come from a Central Bureau of Materials approved processing facility where it shall be ground and processed to 100 percent passing the 3/8 in. (9.5 mm) sieve and 93 percent passing the #4 (4.75 mm) sieve based on a dry shake gradation. RAS shall be uniform in gradation and asphalt binder content and shall meet the testing requirements specified herein. In addition, RAS shall meet the following Type 1 or Type 2 requirements.

   (1) Type 1. Type 1 RAS shall be processed, preconsumer asphalt shingles salvaged from the manufacture of residential asphalt roofing shingles.

   (2) Type 2. Type 2 RAS shall be processed post-consumer shingles only, salvaged from residential, or four unit or less dwellings not subject to the National Emission Standards for Hazardous Air Pollutants (NESHAP).

1031.02 Stockpiles. RAP and RAS stockpiles shall be according to the following.

(a) RAP Stockpiles. The Contractor shall construct individual, sealed RAP stockpiles meeting one of the following definitions. No additional RAP shall be added to the pile after the pile has been sealed. Stockpiles shall be sufficiently separated to prevent intermingling at the base. Stockpiles shall be identified by signs indicating the type as listed below (i.e. "Homogeneous Surface").

   Prior to milling, the Contractor shall request the District provide documentation on the quality of the RAP to clarify the appropriate stockpile.

   (1) Fractionated RAP (FRAP). FRAP shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures. The coarse aggregate in FRAP shall be crushed aggregate and may represent more than one aggregate type and/or quality, but shall be at least C quality. All FRAP shall be fractionated prior

to testing by screening into a minimum of two size fractions with the separation occurring on or between the #4 (4.75 mm) and 1/2 in. (12.5 mm) sieves. Agglomerations shall be minimized such that 100 percent of the RAP shall pass the sieve size specified below for the mix into which the FRAP will be incorporated.

Mixture FRAP will be used in:	Sieve Size that 100 % of FRAP Shall Pass
IL-19.0	1 1/2 in. (40 37.5 mm)
SMA 12.5	1 in. (25.0 mm)
IL-9.5, IL-9.5FG, SMA 9.5	3/4 in. (20 19.0 mm)
IL-4.75	1/2 in. (13 12.5 mm)

(2) Homogeneous. Homogeneous RAP stockpiles shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures and represent: 1) the same aggregate quality, but shall be at least C quality; 2) the same type of crushed aggregate (either crushed natural aggregate, ACBF slag, or steel slag); 3) similar gradation; and 4) similar asphalt binder content. If approved by the Engineer, combined single pass surface/binder millings may be considered "homogeneous" with a quality rating dictated by the lowest coarse aggregate quality present in the mixture.

(3) Conglomerate. Conglomerate RAP stockpiles shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures. The coarse aggregate in this RAP shall be crushed aggregate and may represent more than one aggregate type and/or quality, but shall be at least C quality. This RAP may have an inconsistent gradation and/or asphalt binder content prior to processing. All conglomerate RAP shall be processed prior to testing by crushing to where all RAP shall pass the 5/8 in. (16 mm) or smaller screen. Conglomerate RAP stockpiles shall not contain steel slag.

(4) Non-Quality. RAP stockpiles that do not meet the requirements of the stockpile categories listed above shall be classified as "Non-Quality".

RAP/FRAP containing contaminants, such as earth, brick, sand, concrete, sheet asphalt, bituminous surface treatment (i.e. chip seal), pavement fabric, joint sealants, etc., will be unacceptable unless the contaminants are removed to the satisfaction of the Engineer. Sheet asphalt shall be stockpiled separately.

(b) RAS Stockpiles. Type 1 and Type 2 RAS shall be stockpiled separately and shall not be intermingled. Each stockpile shall be signed indicating what type of RAS is present.

Unless otherwise specified by the Engineer, mechanically blending manufactured sand (FM 20 or FM 22) up to an equal weight of RAS with the processed RAS will be permitted to improve workability. The sand shall be "B Quality" or better from an approved Aggregate Gradation Control System source. The sand shall be accounted for in the mix design and during HMA production.

Records identifying the shingle processing facility supplying the RAS, RAS type, and lot number shall be maintained by project contract number and kept for a minimum of three years.

1031.03 Testing. RAP/FRAP and RAS testing shall be according to the following.

(a) RAP/FRAP Testing. When used in HMA, the RAP/FRAP shall be sampled and tested either during or after stockpiling.

(1) During Stockpiling. For testing during stockpiling, washed extraction samples shall be run at the minimum frequency of one sample per 500 tons (450 metric tons) for the first 2000 tons (1800 metric tons) and one sample per 2000 tons (1800 metric tons) thereafter. A minimum of five tests shall be required for stockpiles less than 4000 tons (3600 metric tons).

(2) After Stockpiling. For testing after stockpiling, the Contractor shall submit a plan for approval to the District proposing a satisfactory method of sampling and testing the RAP/FRAP pile either in-situ or by restockpiling. The sampling plan shall meet the minimum frequency required above and detail the procedure used to obtain representative samples throughout the pile for testing.

Each sample shall be split to obtain two equal samples of test sample size. One of the two test samples from the final split shall be labeled and stored for Department use. The Contractor shall extract the other test sample according to Department procedure. The Engineer reserves the right to test any sample (split or Department-taken) to verify Contractor test results.

(b) RAS Testing. RAS or RAS blended with manufactured sand shall be sampled and tested during stockpiling according to Central Bureau of Materials Policy Memorandum, “Reclaimed Asphalt Shingle (RAS) Source”.

Samples shall be collected during stockpiling at the minimum frequency of one sample per 200 tons (180 metric tons) for the first 1000 tons (900 metric tons) and one sample per 250 tons (225 metric tons) thereafter. A minimum of five samples are required for stockpiles less than 1000 tons (900 metric tons). Once a ≤ 1000 ton (900 metric ton), five-sample/test stockpile has been established it shall be sealed. Additional incoming RAS or RAS blended with manufactured sand shall be stockpiled in a separate working pile as designated in the Quality Control plan and only added to the sealed stockpile when the test results of the working pile are complete and are found to meet the tolerances specified herein for the original sealed RAS stockpile.

Before testing, each sample shall be split to obtain two test samples. One of the two test samples from the final split shall be labeled and stored for Department use. The Contractor shall perform a washed extraction and test for unacceptable materials on the other test sample according to Department procedures. The Engineer reserves the right to test any sample (split or Department-taken) to verify Contractor test results.

If the sampling and testing was performed at the shingle processing facility in accordance with the QC Plan, the Contractor shall obtain and make available all of the test results from start of the initial stockpile.

1031.04 Evaluation of Tests. Evaluation of test results shall be according to the following.

(a) Evaluation of RAP/FRAP Test Results. All of the extraction results shall be compiled and averaged for asphalt binder content and gradation, and when applicable G_{mm}. Individual extraction test results, when compared to the averages, will be accepted if within the tolerances listed below.

Parameter	FRAP/Homogeneous/ Conglomerate
1 in. (25 mm)	
1/2 in. (12.5 mm)	± 8 %
No. 4 (4.75 mm)	± 6 %
No. 8 (2.36 mm)	± 5 %
No. 16 (1.18 mm)	
No. 30 (600 µm)	± 5 %
No. 200 (75 µm)	± 2.0 %
Asphalt Binder	± 0.4 % [1/]
G_{mm}	± 0.03

1/ The tolerance for FRAP shall be ± 0.3 %.

If more than 20 percent of the individual sieves and/or asphalt binder content tests are out of the above tolerances, the RAP/FRAP shall not be used in HMA unless the RAP/FRAP representing the failing tests is removed from the stockpile. All test data and acceptance ranges shall be sent to the District for evaluation.

With the approval of the Engineer, the ignition oven may be substituted for extractions according to the ITP, “Calibration of the Ignition Oven for the Purpose of Characterizing Reclaimed Asphalt Pavement (RAP)”.

(b) Evaluation of RAS and RAS Blended with Manufactured Sand Test Results. All of the test results, with the exception of percent unacceptable materials, shall be compiled and averaged for asphalt binder content and gradation. Individual test results, when compared to the averages, will be accepted if within the tolerances listed below.

Parameter	RAS
No. 8 (2.36 mm)	± 5 %
No. 16 (1.18 mm)	± 5 %
No. 30 (600 µm)	± 4 %

No. 200 (75 µm)	± 2.0 %
Asphalt Binder Content	± 1.5 %

If more than 20 percent of the individual sieves and/or asphalt binder content tests are out of the above tolerances, or if the percent unacceptable material exceeds 0.5 percent by weight of material retained on the # 4 (4.75 mm) sieve, the RAS or RAS blend shall not be used in Department projects. All test data and acceptance ranges shall be sent to the District for evaluation.

1031.05 Quality Designation of Aggregate in RAP/FRAP.

(a) RAP. The aggregate quality of the RAP for homogeneous and conglomerate stockpiles shall be set by the lowest quality of coarse aggregate in the RAP stockpile and are designated as follows.

(1) RAP from Class I, Superpave/HMA (High ESAL), or (Low ESAL) IL-9.5L surface mixtures are designated as containing Class B quality coarse aggregate.

(2) RAP from Class I binder, Superpave/HMA (High ESAL) binder, or (Low ESAL) IL-19.0L binder mixtures are designated as containing Class C quality coarse aggregate.

(b) FRAP. If the Engineer has documentation of the quality of the FRAP aggregate, the Contractor shall use the assigned quality provided by the Engineer.

If the quality is not known, the quality shall be determined as follows. Coarse and fine FRAP stockpiles containing plus #4 (4.75 mm) sieve coarse aggregate shall have a maximum tonnage of 5000 tons (4500 metric tons). The Contractor shall obtain a representative sample witnessed by the Engineer. The sample shall be a minimum of 50 lb (25 kg). The sample shall be extracted according to Illinois Modified AASHTO T 164 by a consultant laboratory prequalified by the Department for the specified testing. The consultant laboratory shall submit the test results along with the recovered aggregate to the District Office. The cost for this testing shall be paid by the Contractor. The District will forward the sample to the Central Bureau of Materials Aggregate Lab for MicroDeval Testing, according to ITP 327. A maximum loss of 15.0 percent will be applied for all HMA applications.

1031.06 Use of RAP/FRAP and/or RAS in HMA. The use of RAP/FRAP and/or RAS shall be the Contractor’s option when constructing HMA in all contracts.

(a) RAP/FRAP. The use of RAP/FRAP in HMA shall be as follows.

(1) Coarse Aggregate Size. The coarse aggregate in all RAP shall be equal to or less than the nominal maximum size requirement for the HMA mixture to be produced.

(2) Steel Slag Stockpiles. Homogeneous RAP stockpiles containing steel slag will be approved for use in all HMA (High ESAL and Low ESAL) Surface and Binder Mixture applications.

(3) Use in HMA Surface Mixtures (High and Low ESAL). RAP/FRAP stockpiles for use in HMA surface mixtures (High and Low ESAL) shall be FRAP or homogeneous in which the coarse aggregate is Class B quality or better. FRAP from Conglomerate stockpiles shall be considered equivalent to limestone for frictional considerations. Known frictional contributions from plus #4 (4.75 mm) homogeneous FRAP stockpiles will be accounted for in meeting frictional requirements in the specified mixture.

(4) Use in HMA Binder Mixtures (High and Low ESAL), HMA Base Course, and HMA Base Course Widening. RAP/FRAP stockpiles for use in HMA binder mixtures (High and Low ESAL), HMA base course, and HMA base course widening shall be FRAP, homogeneous, or conglomerate, in which the coarse aggregate is Class C quality or better.

(5) Use in Shoulders and Subbase. RAP/FRAP stockpiles for use in HMA shoulders and stabilized subbase (HMA) shall be FRAP, homogeneous, or conglomerate.

(6) When the Contractor chooses the RAP option, the percentage of RAP shall not exceed the amounts indicated in Article 1031.06(c)(1) below for a given Ndesign.

(b) RAS. RAS meeting Type 1 or Type 2 requirements will be permitted in all HMA applications as specified herein.

(c) RAP/FRAP and/or RAS Usage Limits. Type 1 or Type 2 RAS may be used alone or in conjunction with RAP or FRAP in HMA mixtures up to a maximum of 5.0 percent by weight of the total mix.

(1) RAP/RAS. When RAP is used alone or RAP is used in conjunction with RAS, the percentage of virgin asphalt binder replacement shall not exceed the amounts listed in the Max RAP/RAS ABR table listed below for the given Ndesign.

RAP/RAS Maximum Asphalt Binder Replacement (ABR) Percentage

HMA Mixtures [1/ 2/]	RAP/RAS Maximum ABR %		
Ndesign	Binder~~/Leveling Binder~~	Surface	Polymer Modified Binder or Surface
30	30	30	10
50	25	15	10
70	15	10	10
90	10	10	10

1/ For Low ESAL HMA shoulder and stabilized subbase, the RAP/RAS ABR shall not exceed 50 percent of the mixture.

2/ When RAP/RAS ABR exceeds 20 percent, the high and low virgin asphalt binder grades shall each be reduced by one grade (i.e. 25 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28). If warm mix asphalt (WMA) technology is utilized and production temperatures do not exceed 275 °F (135 °C), the high and low virgin asphalt binder grades shall each be reduced by one grade when RAP/RAS ABR exceeds 25 percent (i.e. 26 percent RAP/RAS ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

(2) FRAP/RAS. When FRAP is used alone or FRAP is used in conjunction with RAS, the percentage of virgin asphalt binder replacement shall not exceed the amounts listed in the FRAP/RAS table listed below for the given Ndesign.

FRAP/RAS Maximum Asphalt Binder Replacement (ABR) Percentage

HMA Mixtures 1/ 2/	FRAP/RAS Maximum ABR %					
Ndesign	Binder~~/Leveling Binder~~		Surface		Polymer Modified Binder or Surface	
	w/o I-FIT	with I-FIT	w/o I-FIT	with I-FIT	w/o I-FIT	with I-FIT
30	50	55	40	45	10	15
50	40	45	35	40	10	15
70	40	45	30	35	10	15
90	40	45	30	35	10	15
SMA	- -	- -	- -	- -	20	25
IL-4.75	- -	- -	- -	- -	30	35

1/ For Low ESAL HMA shoulder and stabilized subbase, the FRAP/RAS ABR shall not exceed 50 percent of the mixture.

2/ When FRAP/RAS ABR exceeds 20 percent for all mixes, the high and low virgin asphalt binder grades shall each be reduced by one grade (i.e. 25 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28). If warm mix asphalt (WMA) technology is utilized and production temperatures do not exceed 275 °F (135 °C), the high and low virgin asphalt binder grades shall each be reduced by one grade when FRAP/RAS ABR exceeds 25 percent (i.e. 26 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

1031.07 HMA Mix Designs. At the Contractor's option, HMA mixtures may be constructed utilizing RAP/FRAP and/or RAS material meeting the detailed requirements specified herein.

(a) RAP/FRAP and/or RAS. RAP/FRAP and/or RAS mix designs shall be submitted for verification. If additional RAP/FRAP and/or RAS stockpiles are tested and found that no more than 20 percent of the results, as defined under "Testing" herein, are outside of the control tolerances set for the original

RAP/FRAP and/or RAS stockpile and HMA mix design, and meets all of the requirements herein, the additional RAP/FRAP and/or RAS stockpiles may be used in the original mix design at the percent previously verified.

(b) RAS. Type 1 and Type 2 RAS are not interchangeable in a mix design.

The RAP, FRAP, and RAS stone bulk specific gravities (G_{sb}) shall be according to the “Determination of Aggregate Bulk (Dry) Specific Gravity (G_{sb}) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)” procedure in the Department’s Manual of Test Procedures for Materials.

1031.08 HMA Production. HMA production utilizing RAP/FRAP and/or RAS shall be as follows.

(a) RAP/FRAP. The coarse aggregate in all RAP/FRAP used shall be equal to or less than the nominal maximum size requirement for the HMA mixture being produced.

To remove or reduce agglomerated material, a scalping screen, gator, crushing unit, or comparable sizing device approved by the Engineer shall be used in the RAP feed system to remove or reduce oversized material.

If the RAP/FRAP control tolerances or QC/QA test results require corrective action, the Contractor shall cease production of the mixture containing RAP/FRAP and either switch to the virgin aggregate design or submit a new RAP/FRAP design.

(b) RAS. RAS shall be incorporated into the HMA mixture either by a separate weight depletion system or by using the RAP weigh belt. Either feed system shall be interlocked with the aggregate feed or weigh system to maintain correct proportions for all rates of production and batch sizes. The portion of RAS shall be controlled accurately to within ± 0.5 percent of the amount of RAS utilized. When using the weight depletion system, flow indicators or sensing devices shall be provided and interlocked with the plant controls such that the mixture production is halted when RAS flow is interrupted.

(c) RAP/FRAP and/or RAS. HMA plants utilizing RAP/FRAP and/or RAS shall be capable of automatically recording and printing the following information.

(1) Dryer Drum Plants.

a. Date, month, year, and time to the nearest minute for each print.

b. HMA mix number assigned by the Department.

c. Accumulated weight of dry aggregate (combined or individual) in tons (metric tons) to the nearest 0.1 ton (0.1 metric ton).

d. Accumulated dry weight of RAP/FRAP/RAS in tons (metric tons) to the nearest 0.1 ton (0.1 metric ton).

e. Accumulated mineral filler in revolutions, tons (metric tons), etc. to the nearest 0.1 unit.

f. Accumulated asphalt binder in gallons (liters), tons (metric tons), etc. to the nearest 0.1 unit.

g. Residual asphalt binder in the RAP/FRAP material as a percent of the total mix to the nearest 0.1 percent.

h. Aggregate and RAP/FRAP moisture compensators in percent as set on the control panel. (Required when accumulated or individual aggregate and RAP/FRAP are printed in wet condition.)

(2) Batch Plants.

a. Date, month, year, and time to the nearest minute for each print.

b. HMA mix number assigned by the Department.

c. Individual virgin aggregate hot bin batch weights to the nearest pound (kilogram).

d. Mineral filler weight to the nearest pound (kilogram).

e. RAP/FRAP/RAS weight to the nearest pound (kilogram).

f. Virgin asphalt binder weight to the nearest pound (kilogram).

g. Residual asphalt binder in the RAP/FRAP/RAS material as a percent of the total mix to the nearest 0.1 percent.

The printouts shall be maintained in a file at the plant for a minimum of one year or as directed by the Engineer and shall be made available upon request. The printing system will be inspected by the Engineer prior to production and verified at the beginning of each construction season thereafter.

1031.09 RAP in Aggregate Surface Course and Aggregate Wedge Shoulders, Type B. The use of RAP in aggregate surface course (temporary access entrances only) and aggregate wedge shoulders, Type B shall be as follows.

(a) Stockpiles and Testing. RAP stockpiles may be any of those listed in Article 1031.02, except “Non-Quality” and “FRAP”. The testing requirements of Article 1031.03 shall not apply. RAP used shall be according to the current Central Bureau of Materials Policy Memorandum, “Reclaimed Asphalt Pavement (RAP) for Aggregate Applications”.

(b) Gradation. One hundred percent of the RAP material shall pass the 1 1/2 in. (37.5 mm) sieve. The RAP material shall be reasonably well graded from coarse to fine. RAP material that is gap-graded or single sized will not be accepted."

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