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ILLINOIS HIGHWAY MATERIALS SUSTAINABILITY EFFORTS OF 2016

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16. Abstract This report provides a summary of the sustainability efforts of the Illinois Department of Transportation (IDOT) in recycling reclaimed materials in highway construction during calendar year 2016. This report meets the requirements of Illinois Public Act 097-0314 by documenting IDOT's efforts to reduce the carbon footprint and achieve cost savings through the use of recycled materials in asphalt paving projects. Research efforts undertaken and those that will have a future impact on IDOT's sustainability efforts are highlighted. In 2016, 1,795,408 tons of reclaimed or recycled materials, valued at \$50,732,716, were used in Illinois highways. It was estimated that the substitution of reclaimed and recycled materials for virgin materials resulted in a net reduction of carbon dioxide emissions of 166,195 tons.					
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The contents of this report reflect the view of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Illinois Center for Transportation, the Illinois Department of Transportation, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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 presents the materials used in 2016, along with specific reporting on the use of shingles, efforts to reduce the carbon footprint, and efforts to achieve cost savings through the use of recycled materials, as required by Illinois Public Act 097-0314.

The recycled materials currently tracked 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. 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 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 2016, reclaimed and recycled materials totaling 1,795,408 tons were used in Illinois highways. This represents nearly a 214,564-ton or 11% reduction from 2015 quantities. Funding availability 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 2016 increased slightly from 2015 levels, maintaining an approximately fourfold increase over the recycled content of 2009 construction. These materials were valued at \$50,732,716, a reduction of 14% from 2015 due to reduced quantities and changes in value of the various materials in 2016.

The amount of RAS used in 2016 was 29,113 tons, which is a 47% decrease from the 2015 use of 55,362 tons. Technical factors that reduced RAS usage were decreased miles of pavement projects, types of projects, the modification of district special provisions that reduced the maximum allowable asphalt binder replacement (ABR) when polymer modified asphalts are used in the HMA mix and use of database quantities rather than contractor surveys for RAS quantities. Economic factors also impacted usage due the value of bituminous asphalt binder declining from \$453/ton in 2015 to \$334/ton in 2016 which greatly reduced the economic incentive for using RAS. The number of IDOT districts for which contractors produced HMA containing RAS remained at seven in 2016.

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 (CO₂EQ) 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 CO₂EQ emissions 166,195 tons in 2016. The use of fly ash accounted for approximately 46% of the reduction in emissions documented herein.

In 2016, work was conducted on five material sustainability–related research projects, of which two were concluded, two are ongoing, and one was initiated. These efforts resulted in three reports being published at the Illinois Center for Transportation.

Projects that recently produced interim or final reports are as follow:

R27-161: Construction and Performance Monitoring of Various Asphalt Mixes. This ongoing study produced a second interim report to document construction of overlays in 2015 and reported on the performance of all sections under study after the 2015/2016 winter.

R27-162 Chemical and Compositional Characterization of Recycled Binders. This study concluded with a final report that focused on understanding how recycled binder from RAP and RAS impacts the binder’s physical characteristics and performance.

R27-SP28 Evaluation of PG Graded Asphalts with Low Level of Re-Refined Engine Oil Bottoms (ReOB). This study concluded with a final report that evaluated the performance of HMA utilizing ReOB-modified binders.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION	1
CHAPTER 2: USE OF RECLAIMED AND RECYCLED MATERIALS IN ILLINOIS HIGHWAY CONSTRUCTION IN 2016	2
2.1 REPORTING HISTORY.....	2
2.2 RECLAIMED AND RECYCLED MATERIALS ADDED OR DELETED IN 2016	2
2.3 MATERIALS RECLAIMED AND RECYCLED IN 2016.....	2
2.3.1 Determining Recycle Quantities.....	2
2.3.2 Economic Values of Recycled Materials.....	3
2.3.3 Recycled and Reclaimed Material Use and Values for 2016.....	3
2.4 HISTORICAL RECYCLING TRENDS AND DATA ANALYSIS.....	5
2.4.1. Recycling Relationship to Program Budget.....	5
2.4.2 Determination of Recycled Content.....	6
CHAPTER 3: RECLAIMED ASPHALT SHINGLES.....	7
3.1 RAS POLICIES AND SPECIFICATIONS IN EFFECT FOR 2016.....	7
3.1.1 RAS Policy for Sources.....	7
3.1.2 RAS Specifications	7
3.2 QUANTITY OF RAS USED IN CALENDAR YEAR 2016.....	7
CHAPTER 4: ENVIRONMENTAL EVALUATION OF RECYCLED MATERIALS USED IN 2016..	9
4.1 LIFE-CYCLE ASSESSMENT	9
CHAPTER 5: SUSTAINABILITY-RESEARCH ACCOMPLISHMENTS AND INITIATIVES.....	12
5.1 SUSTAINABILITY RESEARCH ACCOMPLISHMENTS CONCLUDED AND ONGOING DURING 2016.....	12
5.1.1 R27-161: Construction and Performance Monitoring of Various Asphalt Mixes ...	12
5.1.2 R27-162 Chemical and Compositional Characterization of Recycled Binders.....	12
5.1.3 R27-168 Field Performance Evaluations of Sustainable Aggregate By-Product Applications (Phase II).....	12
5.1.4 R27-SP28 Evaluation of PG Graded Asphalts with Low Level of REOB.....	13

5.2 PROJECTS INITIATED IN 2016	13
5.2.1 R27-SP31 Evaluation of I-FIT Results and Machine Variability using MnRoad Test Track Mixtures.....	13
CHAPTER 6: CONCLUSIONS	14
REFERENCES	15
APPENDIX A: RECYCLED AND RECLAIMED MATERIALS: QUANTITIES USED AND EQUIVALENT VALUES, 2016.....	17
APPENDIX B: RECYCLING SPECIAL PROVISIONS	18

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; Rowden 2013).

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 the use of recycled materials in asphalt paving projects (IDOT 2013; Lippert and Brownlee 2012; Rowden 2013). The act also required IDOT to allow the use of reclaimed asphalt shingles (RAS) in all hot-mix asphalt (HMA) mixes as long as such use does not cause negative impacts to life-cycle cost.

Illinois has many years of experience using various reclaimed materials in highway construction. These materials tend to be aggregates or materials that extend 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 facets of the use of reclaimed and recycled materials. Chapter 2 presents IDOT's overall use of reclaimed and recycled materials in highway construction projects. Next, Chapter 3 provides a specific look at IDOT's efforts in utilizing RAS in HMA paving. Following that, Chapter 4 presents a life-cycle assessment based on available information which portrays the environmental benefits of recycling the various materials. Finally, Chapter 5 provides an overview of research projects that will provide long-term improvements to the life-cycle of pavements using recycled materials along with other efforts to increase sustainability in the construction of highways.

CHAPTER 2: USE OF RECLAIMED AND RECYCLED MATERIALS IN ILLINOIS HIGHWAY CONSTRUCTION IN 2016

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 2010 construction information was available (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, and 2015 reports provided benchmark performance measures on recycled material use on a per-mile basis rather than total quantity (Lippert et al. 2014, 2015, 2016).

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, 2015, 2016). For this report, the RAS data collection methodology was modified from a contactor survey on use to reliance on data contained in MISTIC.

2.2 RECLAIMED AND RECYCLED MATERIALS ADDED OR DELETED IN 2016

The list of reclaimed and recycled materials used by IDOT was reviewed while preparing this report. No changes, additions, or deletions were made to Regional/District special provisions in 2016. During the 2016 reporting year, no new materials were added or old materials deleted.

2.3 MATERIALS RECLAIMED AND RECYCLED IN 2016

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, as a result 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 2016 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 2017b). For RAP used in HMA, a combination of the annual index average for the asphalt index price and statewide aggregate prices was used to determine the 2016 value. For RAP used as an aggregate, a typical value was determined based upon contractor and supplier feedback on pricing.

2.3.3 Recycled and Reclaimed Material Use and Values for 2016

2.3.3.1 Data for 2016

Appendix A presents the 2016 recycled and reclaimed material quantities and values. In total, 1,795,408 tons of recycled material was used in 2016, which is an 11% decrease in recycled tonnage from 2015. The value of 2016 recycled materials was \$50,732,716, a 14% decrease from 2015. In 2016, the miles of roadway improvement, number of bridges constructed or rehabilitated, and value of projects awarded were all lower, as compared with 2015 figures, and were the main drivers for the decline in recycled quantities.

2.3.3.2 Data Analysis of 2016 Use

To present a more accurate picture of IDOT's recycling effort, a series of figures are presented which provides information on 2016 results, as well as historical trends. As shown in Figure 1, three materials make up the bulk of the recycled tonnage: RAP in HMA mix, followed by recycled concrete material (RCM), and finally RAP as an aggregate.

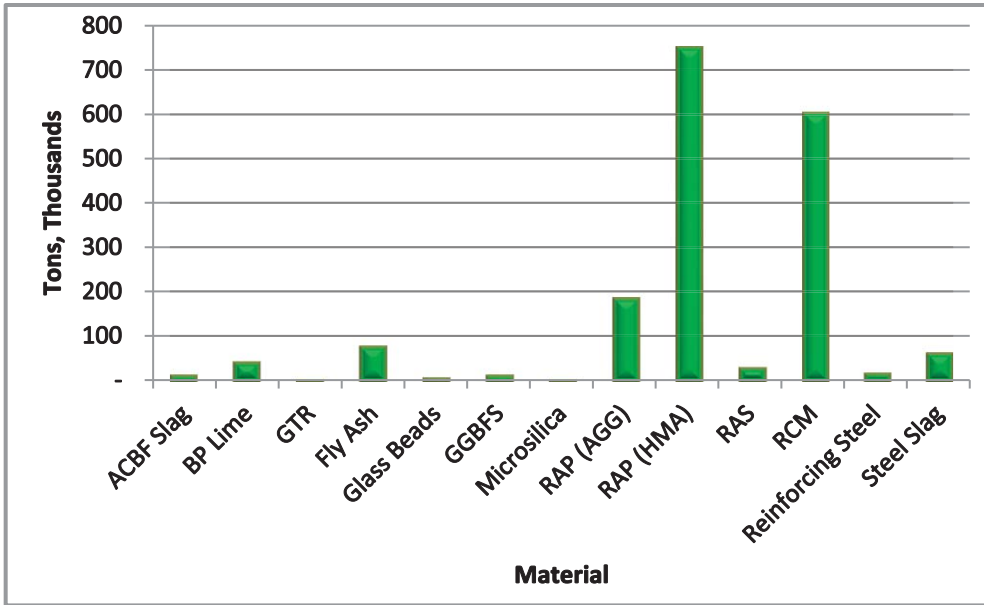


Figure 1. Reclaimed material use in 2016.

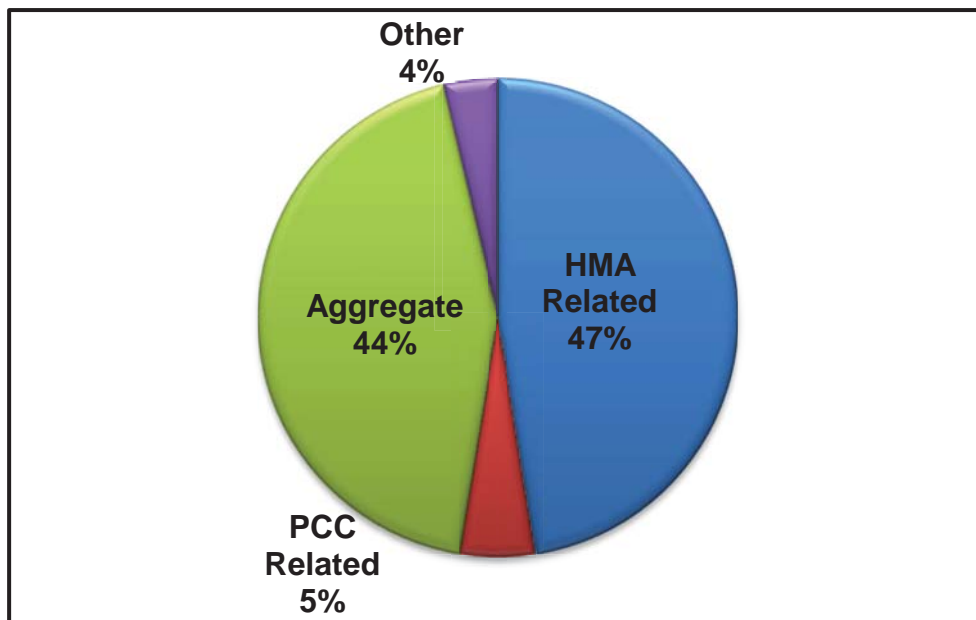


Figure 2. Reclaimed materials by related tons of use in 2016.

Figure 2 breaks out quantities by related uses for HMA, aggregate, concrete, and other. The last 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. Concrete-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, one can see that the majority of recycled tonnage is related to HMA and aggregate uses.

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. Presented in Figure 3 are the total tons recycled from calendar years 2009 through 2016.

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 2017a). 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 the purpose of this effort, it was considered reasonable to use all data as if they had been from the same time period by CY.

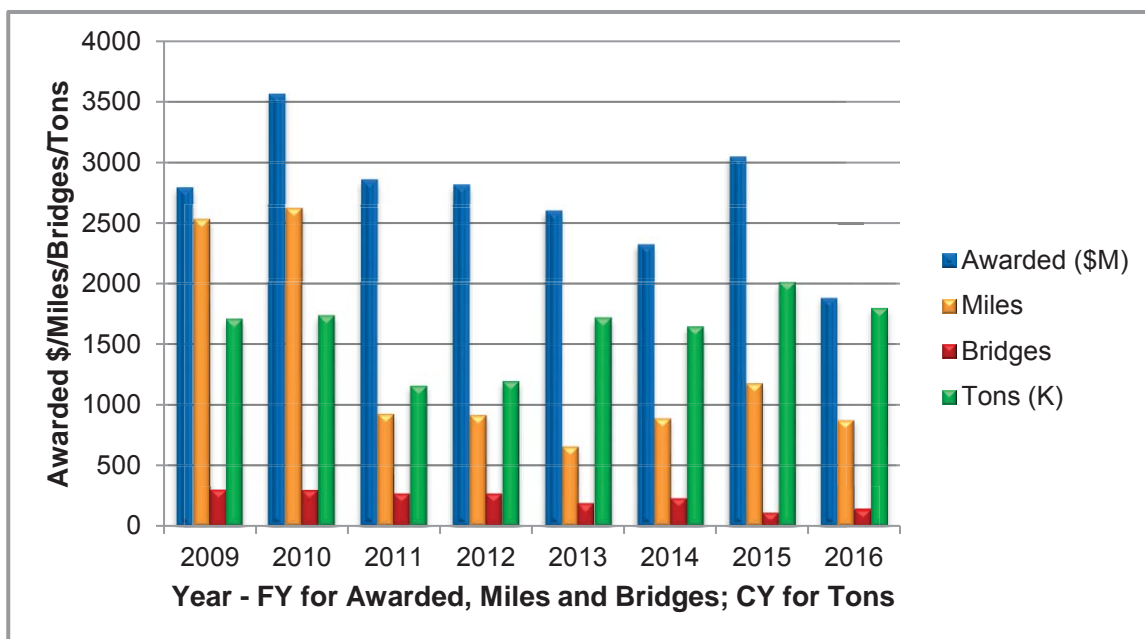


Figure 3. Annual projects awarded (FY), miles improved (FY), bridges built/improved (FY), and recycled tons (CY).

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). That approach is continued here. Figure 4 presents the results of determining the average tons of recycled material for each centerline mile of improvement since 2009. On a tons-per-mile basis, 2016 represents an 18% increase in recycle content from 2015 and an approximately fourfold increase in the use of recycled materials since 2009.

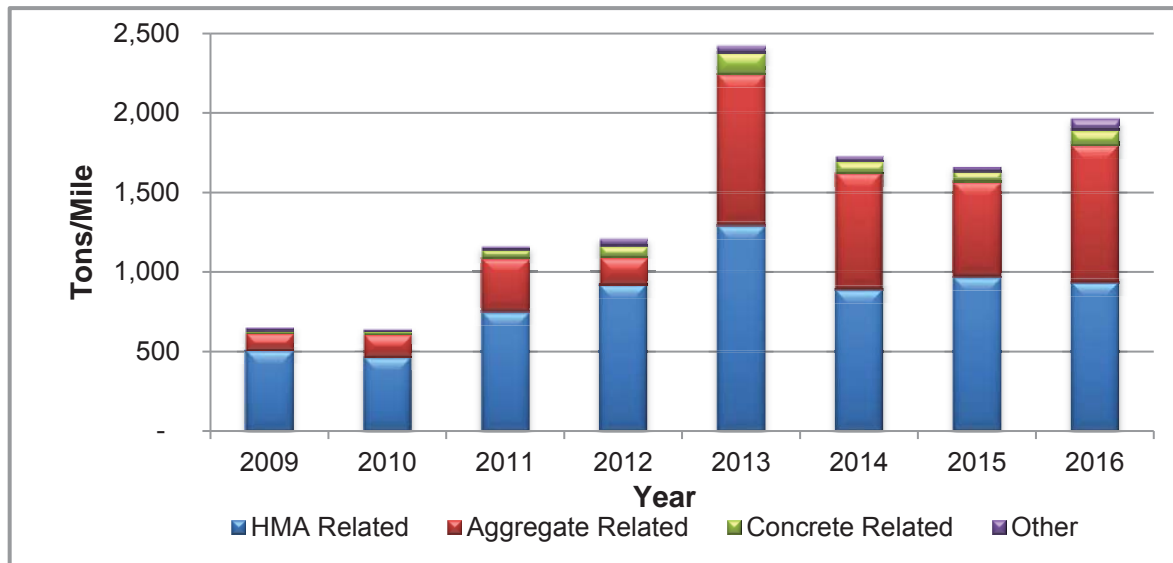


Figure 4. Historical recycle content.

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). MISTIC data were used to report 2016 RAS usage.

3.1 RAS POLICIES AND SPECIFICATIONS IN EFFECT FOR 2016

3.1.1 RAS Policy for Sources

The Bureau of Materials and Physical Research (BMPR) Policy Memorandum, “Reclaimed Asphalt Shingle (RAS) Sources” (28-10.3), continued to be in effect for all 2016 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 2016, IDOT added several new RAS suppliers, increasing the total to 21 (IDOT 2016b).

3.1.2 RAS Specifications

3.1.2.1 Statewide Specifications

The Bureau of Design and Environment (BDE) specification, “Reclaimed Asphalt Shingles (RAS) (BDE),” effective January 1, 2012, was revised on April 1, 2016, resulting in different specifications being used in 2016, depending upon letting date. Revisions were to fit with the 2016 Standard Specifications and incorporated the revisions from January 2, 2015. The revised specification effective April 1, 2016, is provided in Appendix B.

3.1.2.2 Regional/District Specifications

During 2016, the Regions/Districts did not modify specifications they had in use; or they utilized the statewide specification noted above (Lippert et al. 2014, 2015, 2016).

3.2 QUANTITY OF RAS USED IN CALENDAR YEAR 2016

In 2016, IDOT experienced a decrease in RAS use. The total used in 2016 was 29,112 tons, which was a 47% reduction from the 55,362 tons in 2015 (Lippert et al. 2016). The decrease can be attributed to a 25% reduction in roadway-improvement miles paved, as well as a reduction in ABR rates when polymer asphalts are specified in district special provisions.

Also impacting the amount of RAS used was the decline in crude oil prices and closely related bituminous asphalt binder prices the past several years. Bituminous prices as reflected in IDOT’s price index averaged \$453 in 2015 declined to \$334 in 2016 (IDOT 2017b). The price of RAS has been in the \$40 to \$45 range the past few years (Lippert et al. 2014, 2015, 2016). Using a typical asphalt binder content of 25% for RAS translates into a bituminous asphalt binder value in the range of \$160 to \$180/ton. The cost savings for replacing bituminous asphalt binder with reclaimed asphalt binder contained in RAS was greatly impacted in 2016, thus reducing the economic incentive for RAS usage.

In 2016, seven of the districts reported use of RAS, which is the same number as the previous year. Figure 5 presents the percentage of the 2016 statewide total RAS used by each IDOT district.

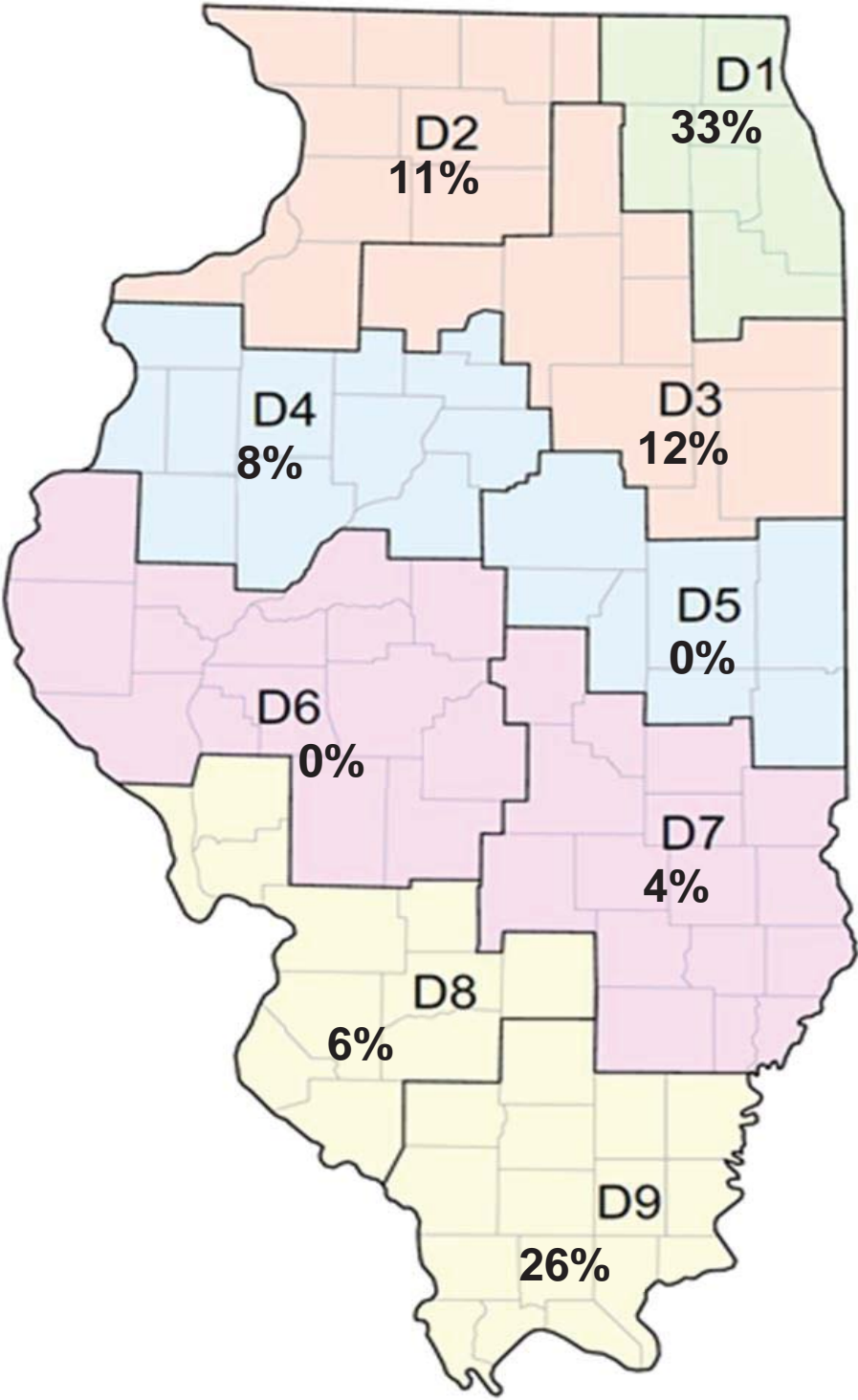


Figure 5. Percentage of RAS used by each district in calendar year 2016.

CHAPTER 4: ENVIRONMENTAL EVALUATION OF RECYCLED MATERIALS USED IN 2016

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 partly 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 in 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 CO₂EQ/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 CO₂EQ/ton for each material recycled and the virgin material being replaced. The difference in CO₂EQ/ton between virgin and recycled material is the "savings" noted in Table 1 for each material, in kilograms equivalent of CO₂ 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 2016, the total CO₂EQ 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.

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

Material	Savings per Ton of Use, CO₂EQ (kg)	2016 CO₂EQ Savings (Tons)
Air-Cooled Blast Furnace Slag	13	179
By-Product Lime	920	42,750
Crumb Rubber	1704	53
Fly Ash	894	76,392
Glass Beads	929	6,295
Ground Granulated Blast Furnace Slag	763	10,249
Microsilica	Not Available (NA)	NA
Reclaimed Asphalt Pavement Used For HMA	17	14,036
Reclaimed Asphalt Pavement Used For Aggregate	0.8	164
Reclaimed Asphalt Shingles	79	2,535
Recycled Concrete Material	0.8	530
Steel Reinforcement	640	11,840
Steel Slag	17	1,172
Wet-Bottom Boiler Slag	NA	NA

Materials that have low CO₂EQ, 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 CO₂EQ can be realized.

From this simple analysis, it is estimated that a total of 166,195 tons of CO₂EQ was saved in 2016. Appendix A presents an accounting of CO₂EQ saved in 2016 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 2016 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 CO₂EQ savings by related use, which differs greatly from the tonnage distribution presented previously in Figure 2.

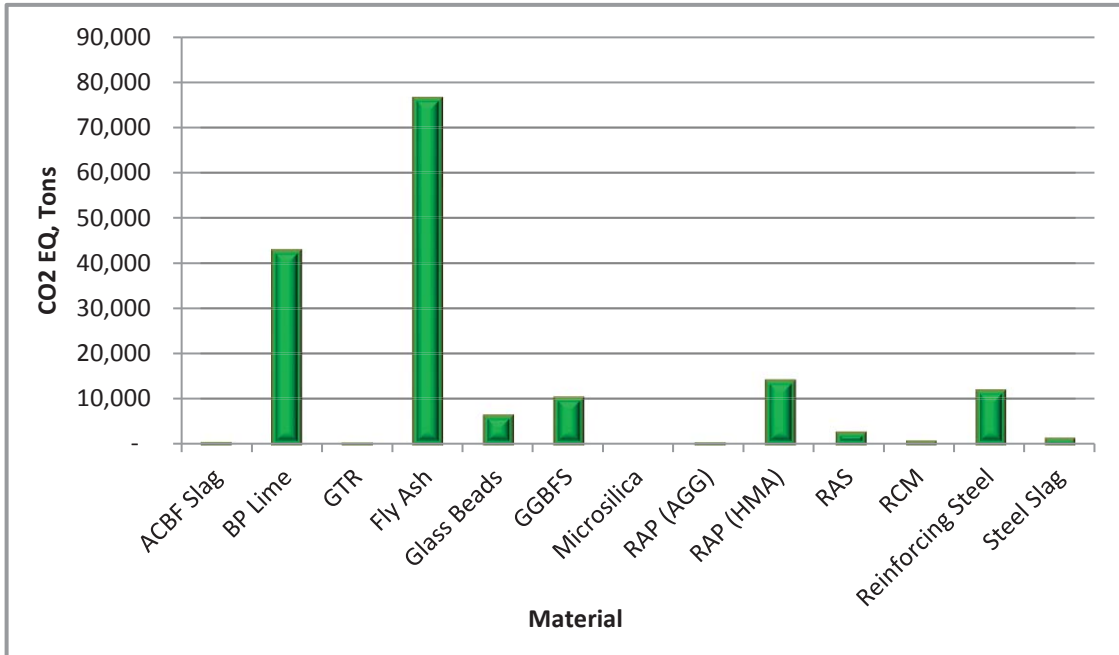


Figure 6. CO₂EQ saved, by material, in 2016.

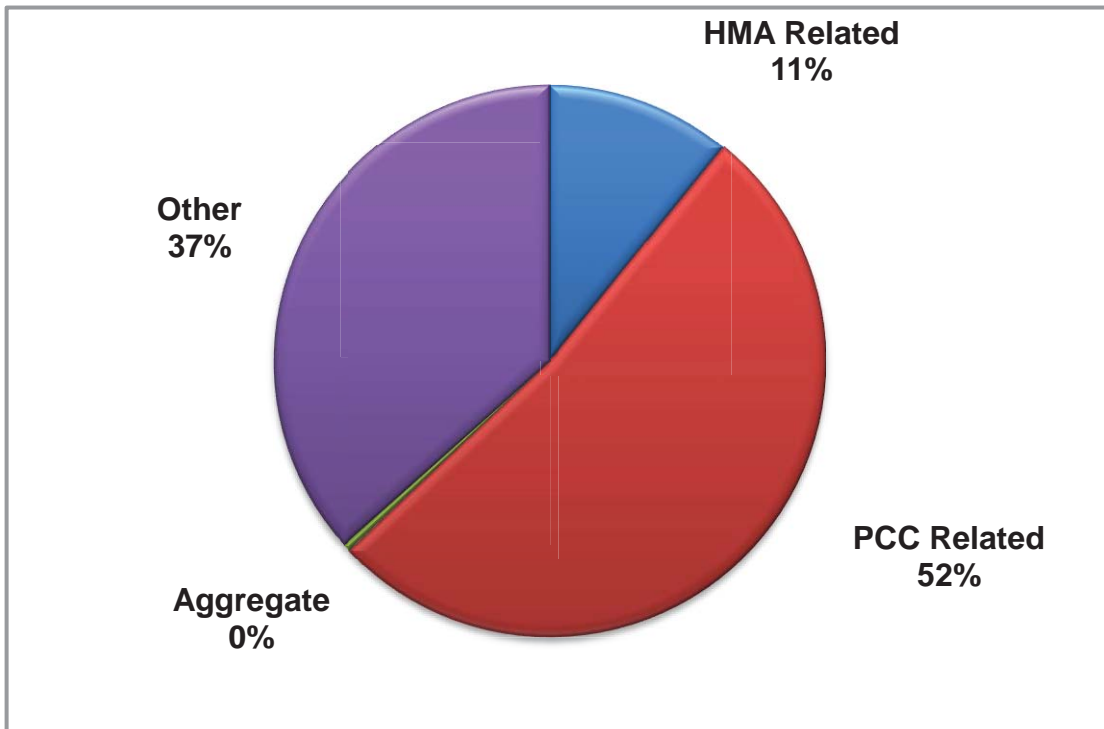


Figure 7. CO₂EQ saved, by related use, in 2016.

CHAPTER 5: SUSTAINABILITY-RESEARCH ACCOMPLISHMENTS AND INITIATIVES

During 2016, IDOT had five sustainability-related studies underway with ICT. These efforts focused on aggregate and HMA use of recycled materials. Three of these studies produced an interim or final report. Two studies concluded, with work continuing on two. A brief status of each effort is provided. One new material sustainability research effort was initiated in 2016.

5.1 SUSTAINABILITY RESEARCH ACCOMPLISHMENTS CONCLUDED AND ONGOING DURING 2016

5.1.1 R27-161: Construction and Performance Monitoring of Various Asphalt Mixes

This study, entering its third year, is an intensive study of basic materials properties from production of the mixture, construction of the pavement, and through the years that follow to evaluate how the pavement performs over time. Tasks include a pre-construction pavement evaluation, construction surveys and quality assurance, laboratory characterization of materials collected at the time of production, a post-construction survey, and in-service field surveys over the life of the study. An interim report that covers construction and early pavement performance is available (Lippert et al. 2017). The study is projected to conclude on schedule in December 2017.

5.1.2 R27-162 Chemical and Compositional Characterization of Recycled Binders

This study began in January 2015 and focused on understanding how the addition of recycled binder from RAP and RAS affects the structural and compositional characteristics/properties of virgin/aged binder blends and how that translates to the binder's physical characteristics and the performance of mixes during service life. The study concluded with publication of a final report (Sharma 2017).

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

In its second year, this study is intended to determine from field performance evaluations the most successful sustainable/green applications utilizing large quantities of quarry by-product fines (QBs) in road construction. Full-scale test sections have been constructed to demonstrate innovative and sustainable uses of QB applications. The constructed pavement sections are in the process of being tested using the University of Illinois's accelerated pavement-testing equipment to evaluate field performances of the most promising QB applications. The study will produce 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. A report is expected in 2018.

5.1.4 R27-SP28 Evaluation of PG Graded Asphalts with Low Level of ReOB

This study evaluated the properties of asphalt binder modified with re-refined engine oil bottoms (ReOB) products (e.g. WEO, RHVDO, and RVTB) or the non-distillation fraction of re-refined waste engine oils, and their effect on HMA-mixture benchmark performance tests. The objectives of this study were to evaluate both the characteristics of PG asphalt binders modified with ReOB and the performance of HMA mixtures utilizing ReOB-modified binders. The study concluded with publication of a final report (Ozer 2016).

5.2 PROJECTS INITIATED IN 2016

5.2.1 R27-SP31 Evaluation of I-FIT Results and Machine Variability using MnRoad Test Track Mixtures

This special study compares the I-FIT results using two different machine types: the screw-drive type and the servo-hydraulic machine. Materials collected from the MnRoad test track will be tested to evaluate the influence of machine compliance on the I-FIT test and to determine correction factors that need to be applied based on machine type, if any. A report is expected to be published in 2017.

CHAPTER 6: CONCLUSIONS

The goal of this report is to provide a single-source document for 2016 sustainability efforts in highway materials that serves to meet the reporting requirement of Illinois Public Act 097-0314. On the basis of the 2016 efforts, the following conclusions can be made:

- In 2016, recycled materials used in highway projects totaled 1,795,408 tons, with a value of \$50,732,716.
- Usage of reclaimed asphalt shingles (RAS) in 2016 decreased 47% from 2015 levels. Likewise reclaimed asphalt pavement (RAP) used for HMA decreased 29% from 2015. Main causes for declines in RAP and RAS use was the 25% reduction in miles of roadway improvement from 2015 to 2016 and lower crude oil prices which impacted the economics of recycled material use. Past specification changes that reduced the maximum asphalt binder replacement levels allowed in polymer-modified asphalt mixes were in full effect for 2016 projects which also contributed to the reduction in RAS.
- Using Life-cycle assessment (LCA) and available information, it is estimated that carbon dioxide–equivalent emissions were reduced by 166,195 tons in 2016. The majority of the reduction was from the use of fly ash to replace cement, by-product lime being used in place of hydrated lime for soil modification, and RAP being used in asphalt pavements.
- With respect to material sustainability research projects in 2016, the department concluded two projects and initiated one project, with two projects ongoing. These research projects resulted in a total of three publications in the form of interim/final reports.

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APPENDIX A: RECYCLED AND RECLAIMED MATERIALS: QUANTITIES USED AND EQUIVALENT VALUES, 2016

Material	Unit Equivalent Value	Quantity ¹ Tons	Total Equivalent Value to Department	CO ₂ Equivalent Savings Tons ⁶
Air-cooled blast furnace slag	\$10.00	12,465	\$124,650	179
By-product lime	\$35.00	42,155	\$1,475,425	42,750
Crumb rubber ²	\$400.00	28	\$11,250	53
Fly ash	\$15.00	77,519	\$1,162,785	76,392
Glass beads ³	\$626.00	6,147	\$3,847,897	6,295
Ground granulated blast furnace slag	\$85.00	12,186	\$1,035,810	10,249
Microsilica	\$500.00	82	\$41,000	NA
Reclaimed asphalt pavement used for HMA	\$29.78	748,990	\$17,825,962	14,036
Reclaimed asphalt pavement used for aggregate	\$7.50	186,106	\$1,395,795	164
Reclaimed asphalt shingles	\$46.11	29,113	\$1,342,400	2,535
Recycled concrete material	\$7.50	601,268	\$4,509,510	530
Steel reinforcement ⁴	\$999.84	16,784	\$16,740,214	11,840
Steel slag	\$19.50	62,565	\$1,220,018	1,172
Wet-bottom boiler slag ⁵	NA	NA	NA	NA
Totals	—	1,795,408	\$50,732,716	166,195

¹ Quantities were calculated from amounts assigned to projects in calendar year 2016. 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 2016.

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 2016 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 2016.

⁶ Based on typical haul distances for Illinois and industrial averages between virgin material and recycled/reclaimed material found in the literature.

APPENDIX B: RECYCLING SPECIAL PROVISIONS

RECLAIMED ASPHALT PAVEMENT AND RECLAIMED ASPHALT SHINGLES (BDE)

Effective: November 1, 2012

Revise: ~~April 1, 2014~~ April 1, 2016

Revise Section 1031 of the Standard Specifications to read:

“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 Bureau of Materials and Physical Research Policy Memorandum, “Reclaimed Asphalt Shingle (RAS) Sources”, by weight of RAS. All RAS used shall come from a Bureau of Materials and Physical Research 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-25.0	2 in. (50 mm)
IL-19.0	1 1/2 in. (40 mm)
IL-12.5	1 in. (25 mm)
IL-9.5	3/4 in. (20 mm)
IL-4.75	1/2 in. (13 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) Conglomerate "D" Quality (DQ). Conglomerate DQ RAP stockpiles shall consist of RAP from Class I, HMA (High or Low ESAL), or "All Other" (as defined by Article 1030.04(a)(3)) mixtures. The coarse aggregate in this RAP may be crushed or round but shall be at least D quality. This RAP may have an inconsistent gradation and/or asphalt binder content. Conglomerate DQ RAP stockpiles shall not contain steel slag.~~

- ~~(54)~~ 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 Illinois Department of Transportation Bureau of Materials and Physical Research 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 "D" Quality
1 in. (25 mm)	$\pm 5\%$
1/2 in. (12.5 mm)	$\pm 8\% \pm 15\%$
No. 4 (4.75 mm)	$\pm 6\% \pm 13\%$
No. 8 (2.36 mm)	$\pm 5\%$
No. 16 (1.18 mm)	$\pm 15\%$
No. 30 (600 μm)	$\pm 5\%$
No. 200 (75 μm)	$\pm 2.0\% \pm 4.0\%$
Asphalt Binder	$\pm 0.4\% \text{ }^{1/} \pm 0.5\%$
G_{mm}	± 0.03

1/ The tolerance for FRAP shall be $\pm 0.3\%$.

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 ~~Illinois Test Procedure~~ 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)	$\pm 5\%$
No. 16 (1.18 mm)	$\pm 5\%$
No. 30 (600 μm)	$\pm 4\%$
No. 200 (75 μm)	$\pm 2.0\%$
Asphalt Binder Content	$\pm 1.5\%$

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, ~~and conglomerate~~ "D" quality 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 is~~ designated as containing Class ~~D-C~~ quality coarse aggregate.

~~(3) RAP from Class I, Superpave/HMA (High ESAL) binder mixtures, bituminous base course mixtures, and bituminous base course widening mixtures are designated as containing Class C quality coarse aggregate.~~

~~(4) RAP from bituminous stabilized subbase and BAM shoulders are designated as containing Class D 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 Bureau of Materials and Physical Research Aggregate Lab for MicroDeval Testing, according to ~~Illinois Modified AASHTO T 164~~ 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 a ~~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. RAP/FRAP from Conglomerate stockpiles shall be

considered equivalent to limestone for frictional considerations. Known frictional contributions from plus #4 (4.75 mm) homogeneous RAP and 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, ~~or conglomerate DQ~~.
 - (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
30	30	30	10
50	25	15	10
70	15	10	10
90 105	10 10	10 10	10 10

1/ For Low ESAL HMA ~~“All Other”~~ (shoulder and stabilized subbase) ~~N-30~~, 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 <i>1/, 2/</i>	FRAP/RAS Maximum ABR %		
	Ndesign	Binder/Leveling Binder	Surface
30	50	40	10
50	40	35	10
70	40	30	10
90 105	40 40	30 30	10 10

- 1/ For Low ESAL HMA "~~All Other~~" (shoulder and stabilized subbase) ~~N30~~, 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).
- 3/ For SMA the FRAP/RAS ABR shall not exceed 20 percent.
- 4/ For IL-4.75 mix the FRAP/RAS ABR shall not exceed 30 percent.

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. A RAS stone bulk specific gravity (Gsb) of 2.300 shall be used for mix design purposes.

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 material passing the sizing device adversely affects the mix production or quality of the mix, the sizing device shall be set at a size specified by the Engineer.

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 ~~to construct aggregate surface course and aggregate shoulders~~ shall be according to the current Bureau of Materials and Physical Research's 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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