

2024 Ontario Paving Report  
Published April-2024

Amin Mneina, MSc., P.Eng.  
Senior Specialist, Technical Programs &  
Research, Good Roads

James Smith, PhD.  
Manager, Technical Programs & Re-  
search, Good Roads

Doubra Ambaiowej, PhD. P.Eng.  
Technical Director, OAPC/ORBA

# Good Roads

in association with



# Table of Contents

3	Background	1.1 Message from Stakeholders
		1.2 Report Objectives
		1.3 History of RAP in Ontario
4		1.4 Municipal Paving Forecast Survey
		1.5 Ontario RAP Survey
5	Paving Materials Utilization (Quantitative Analysis)	2.1 Hot Mix Asphalt (HMA)
		2.1.1 Total Produced HMA
		2.1.2 Consumed HMA in Municipal Paving
6		2.2 Reclaimed Asphalt Pavement (RAP)
		2.2.1 Total Available RAP
7		2.2.2 Consumed RAP in Municipal Paving
8		2.3 Warm Mix Asphalt (WMA)
		2.4 In-Place Recycling (HIR/CIR)
9	State of the Practice with RAP	3.1 Municipal RAP Specifications
		3.2 RAP Stockpile Management (Industry and Municipalities)
10		3.3 RAP Processing (Industry and Municipalities)
12	RAP Source Best Practices	4.1 Stockpiling
		4.1.1 Methods (Truck & Loader vs. Stacking Conveyor)
		4.1.2 Protect from Contamination
13		4.1.3 Minimize Trapped Moisture
		4.1.4 Minimize Compaction
		4.1.5 Minimize Segregation
14		4.1.6 Other Stockpiling Considerations
		4.2 Processing & Crushing
		4.2.1 Screening Before Crushing
		4.2.2 Fractionation
		4.2.3 Processing of millings
15		4.2.4 RAP Crushing
		4.3 Sampling & Testing
		4.3.1 Recommended Tests
		4.3.2 Sampling Frequency
		4.3.3 Sampling Procedure
		4.3.4 Recommended Maximum Variability
16	References	

## Message from stakeholders

Good Roads recognized the need to obtain accurate and current data on paving practices, trends, and quantities, of materials used in municipal asphalt paving to be able to better monitor and evaluate the effects of current practices and specification on the consumption of paving materials including RAP. This report captures the dedicated collaboration among stakeholders in the road and infrastructure sector. The initiative leading to this report started in 2019 with RAP quantity estimation from satellite images, then evolved to be a collaboration study between Good Roads GR, Ontario Asphalt Pavement Council (OAPC – a Council of Ontario Road Builders’ Association, ORBA), the Municipal Engineers Association (MEA), to quantify the amounts and identify best practices of RAP stockpiling in Ontario. In this report, Ontario is divided into four geographical zones (Northern, Southeast, Southwest, and Central) as presented in Figure 1

## Report Objectives

- Report annual municipal HMA paving tonnage to facilitate strategic planning.
- Document material availability of RAP compared to municipal paving needs across Ontario.
- Document the historical background of RAP use in Ontario.
- Report vital metrics on RAP stockpiling inventory in Ontario.
- Present an Ontario state of the practice on municipal paving.
- Synthesise information on best practices for RAP processing, and stockpile management and identify the most relevant documents for further details.
- Provide a platform for sharing and documenting long lasting successful applications of RAP paving in Ontario municipalities.
- Build a sound evidence base for promoting the economic and environmental benefits of using of RAP in road building across Ontario

## History of RAP in Ontario

The earliest efforts in recycling asphalt concrete into new pavement constructions consisted of pulverization of existing pavements to use in new subbase layers. Earliest records of this recycling practice date back to the 1960s in Nevada as well as Ontario, and 1975 in Texas (Clark et al., 1978; McLuckie et al., 1987). Since then, the use of recycled hot mix asphalt was introduced to the infrastructure industry and gained widespread acceptance in North America. In 1979, the Ministry of Transportation Ontario (MTO) implemented its first efforts to adopt recycled hot mix asphalt as a standard pavement recycling alternative (McLuckie et al., 1987). The rapidly increasing prices of crude oils in 1970s’ was the main driving force behind reusing the existing asphalt binder in aged flexible pavements (Copeland,

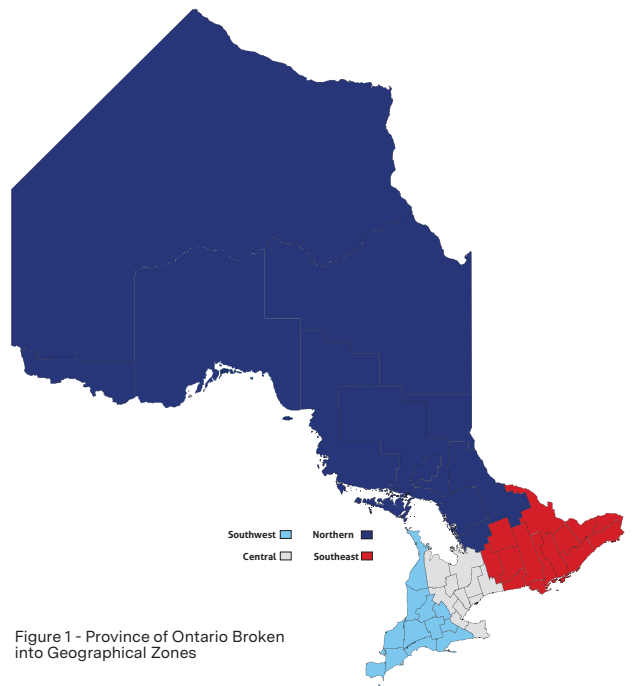


Figure 1 - Province of Ontario Broken into Geographical Zones

2011). However, in addition to the economic motivations, nowadays RAP usage is proven to yield several benefits in terms of saving landfill spaces and preventing the rapid depletion of natural resources such as aggregates and virgin asphalt binder (Tavassoti-Kheiry, 2016). The use of RAP in hot mix continued to gain acceptance and shortly became adopted in all 50 states of the USA in 1982. Currently, in the United States, an approximate 98% of all milled pavements were reclaimed, and 96 million tonnes of RAP were used and in 2017, making RAP the most recycled material in North America (Williams et al., 2018). In the past years, there has been a growing awareness towards sustaining aggregate resources (EBA Engineering, 2013; Ministry of Natural Resources Ontario, 2010). According to The Ontario Aggregate Resource Corporation (2014), approximately 153 million tonnes of aggregates are produced each year in Ontario, out of which, 50% is used in the maintenance and construction of infrastructure in Ontario. This gives RAP the potential to be a significant contributor to aggregate sustainability. In addition to saving valuable diminishing aggregate resources, using RAP in infrastructure contributes to the following:

- Recovering non-renewable petrochemical resources
- Reducing road building costs
- Diverting large amount of solid waste from landfills
- Reducing greenhouse gases emissions

## Municipal Paving Forecast Survey

The Municipal Paving Forecast is a longstanding initiative driven by a commitment to excellence since its inception in 2016. It is spearheaded by Good Roads. Working in partnership with the Ontario Asphalt Pavement Council (OAPC – a Council of Ontario Road Builders’ Association, ORBA) through the GR/OAPC Municipal HMA Liaison Committee. The survey collects information from Municipalities on projected paving tonnage, RAP usage, and other road building practice matters. The results of the survey are subjected to thorough scrutiny, ensuring reliability and precision in the data collected. Through this collaborative effort, the Municipal Paving Forecast serves as a vital resource for informed decision-making and strategic planning in the field of municipal road construction and maintenance in Ontario.

## Ontario RAP Inventory

The Ontario RAP Survey initiative started in 2019 where Good Roads conducted a study on RAP quantity estimation using satellite images which was published in the 2019 TAC Conference proceedings. Then initiative then gained momentum and evolved to be a collaboration study between Good Roads GR, Ontario Asphalt Pavement Council (OAPC – a Council of Ontario Road Builders’ Association, ORBA), the Municipal Engineers Association (MEA), to produce current and historical special data on RAP stockpiles quantities in Ontario.

## Hot Mix Asphalt (HMA)

This section will discuss the trends on HMA production quantities, locations, and municipal paving consumption of HMA.

### 2.1.1 Total Produced HMA

Although municipal asphalt paving projects account for a large share of the total HMA produced in Ontario, it is still important to monitor the total HMA production trends and locations. Table-1 presents a reported summary of the HMA production facilities locations and their annual production in the past years. Figure-2 shows a spatial heatmap representation of the total HMA production data in Ontario.

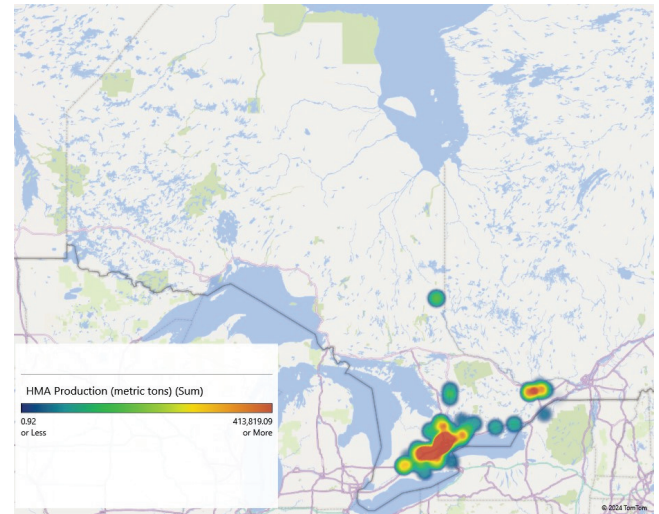


Figure 2 - HMA Production Tonnage Distribution in Ontario

### 2.1.2 Consumed HMA in Municipal Paving

Based on survey responses, a total of 1.2M tonnes of HMA is estimated to be used in municipal paving projects for the 2024 construction season. A summary of the HMA paving quantities per year are presented in Table 2 and Figure-3. The quantities are summarized as per geographical zones. It is noted that the Central Zone had always accounted for most of the municipal paving tonnage with an average annual share of 46% from the total municipal HMA tonnage. It should be noted that the numbers for 2024 do not include the City of Toronto.

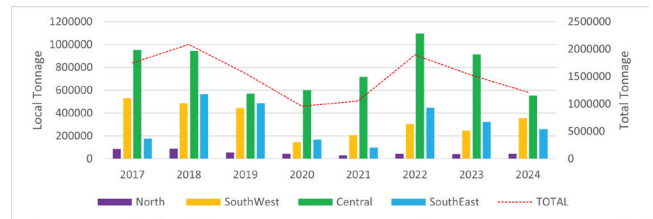


Figure 3 - Annual Reported Municipal HMA Paving Tonnage

## Total HMA Production (Tonnes)

Year	Facilities	North	SouthWest	Central	SouthEast	TOTAL
2022	72	459,756 (8%)	1,100,611 (19%)	3,781,868 (66%)	648,700 (11%)	5,690,935
2023	94	171,000 (2%)	1,222,444 (17%)	4,840,826 (66%)	1,110,881 (15%)	7,345,151

Table 1 - Total HMA Production Tonnage in Ontario

## Municipal HMA Paving (Tonnes)

Year	Municipalities	North	SouthWest	Central	SouthEast	TOTAL
2017	54	87400 (5%)	531289 (30%)	952400 (55%)	174836 (10%)	1,745,925
2018	44	90300 (4%)	487810 (23%)	944905 (45%)	564807 (27%)	2,087,822
2019	58	54446 (4%)	443525 (29%)	569815 (37%)	486765 (31%)	1,554,551
2020	40	44925 (5%)	143680 (15%)	601915 (63%)	169341 (18%)	959,861
2021	43	30100 (3%)	207988 (20%)	718399 (68%)	97453 (9%)	1,053,940
2022	57	44150 (2%)	303530 (16%)	1097509 (58%)	448105 (24%)	1,893,294
2023	64	43010 (3%)	246377 (16%)	913288 (60%)	323486 (21%)	1,526,161
2024	54	45307 (4%)	357245 (29%)	553773 (46%)	260018 (20%)	1,216,343

Table 2 - Municipal Hot-Mix Paving Quantities in Ontario

Through an extrapolation from the Municipal Paving Forecast data 2017-2021 it is estimated that in any given year, Ontario municipalities pave between 4.9M and 5.2M tonnes of HMA. These estimates counter the popular opinion which believes that MTO is the largest user of HMA at 2.5-3M tonnes/year. In the past eight years (2017-2024) the paving average represented the following percentages for each geo-zone: [N=4%, SW=22%, C=54%, SE=20%].

## Reclaimed Asphalt Pavement (RAP)

### 2.2.1 Total Available RAP

Table 3 presents a summary of facilities containing RAP in each geographical zone and their total reported un-processed RAP inventory per year. The RAP quantities in the table do not include RAP that is stockpiled in municipal facilities as in 2020, it was found that RAP stockpiles in municipal facilities represented only 5% of the total inventory. It is worth noting that (Mneina & Smith, 2019) observed a 91% increase in RAP in the Southwest zone over a ten-year period (2008-2018) by investigating historical satellite images.

### RAP Inventory in Ontario (Tonnes)

Year	Facilities	North	SouthWest	Central	SouthEast	TOTAL
2019	57	868,418	263,007	1,901,174	1,280,015	4,312,614
2020	39	299,000	287,296	1,434,510	260,000	2,280,806
2021	60	27,500	370,269	1,815,253	739,899	2,952,920
2022	72	229,993	413,435	1,839,396	791,342	3,274,166
2023	94	245,000	684,177	1,909,738	836,061	3,606,461

Table 3 - RAP Inventory in Ontario as Reported in the Ontario RAP Survey

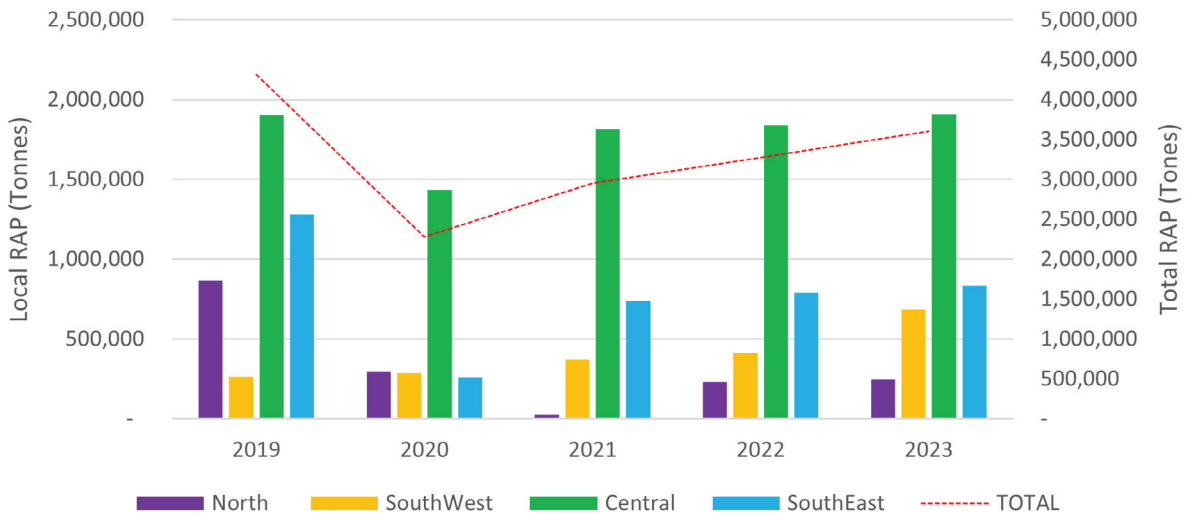


Figure 4 - Annual Reported RAP Quantities

### 2.2.2 Consumed RAP in Municipal Paving

Availability of information on local quantities and practices of RAP in HMA paving is a key resource in the continuous improvement and growth of this industry's stakeholders.

Estimating the municipal RAP consumption was made using the Municipal Paving survey results, assumptions, and simple calculations. Through the 2024 survey, information was collected on how much of municipal paving projects incorporated RAP in each municipality. Conservative assumptions were made that 15% RAP in HMA was used in projects that incorporated RAP. The estimated consumed

RAP was then calculated based on the assumptions and the known paving tonnage of 54 municipalities. Although this estimate represents only 54 out of 444 municipalities, it is considered an accurate estimation as these 64 municipalities represent 47% of the total population of Ontario which strongly correlate to the road building activity and network distribution around the province. The bubble diagram in Figure 5 presents the 2024 projected RAP consumption locations and quantities alongside the RAP inventory locations and quantities.

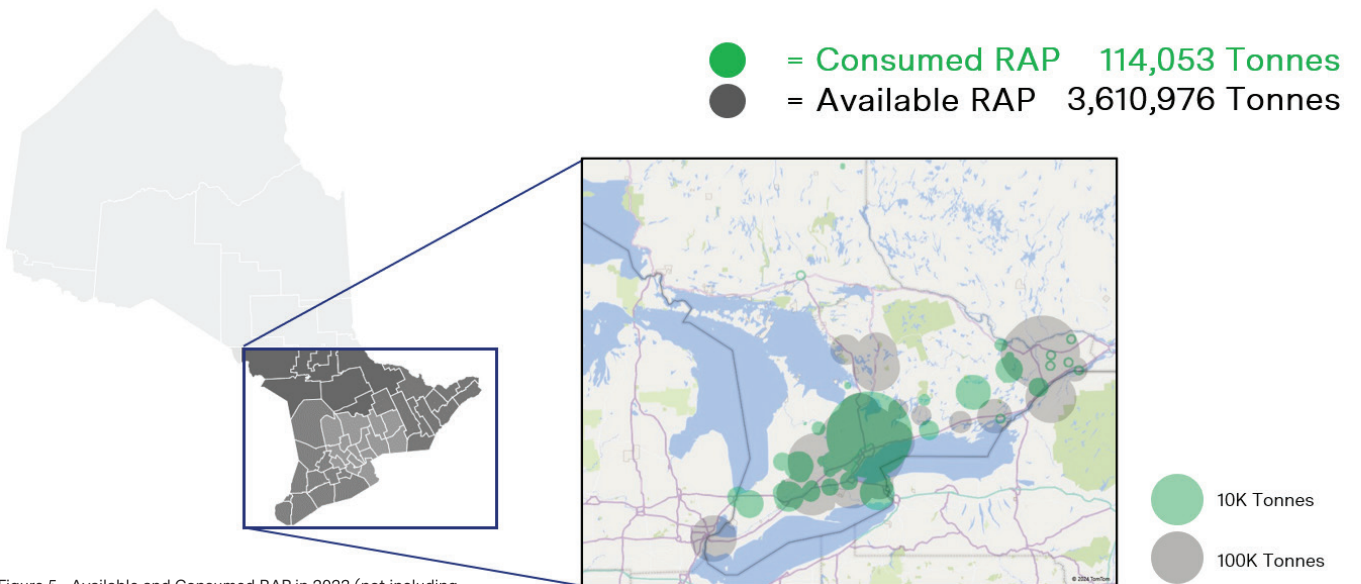


Figure 5 - Available and Consumed RAP in 2023 (not including MTO's consumption)

### Total Municipal RAP Consumption (Tonnes)

Year	Municipalities	North	SouthWest	Central	SouthEast	TOTAL
2023	64	4,000	22,000	104,000	33,000	163,360
2024	54	3,468	28,961	65,231	15,504	113,145

Table 4- Municipal Consumed RAP

### Warm Mix Asphalt (WMA)

Warm Mix Asphalt (WMA) represents a revolutionary advancement in the field of road construction, offering a more sustainable and environmentally friendly alternative to traditional Hot Mix Asphalt (HMA). WMA technology allows for the production and placement of asphalt mixtures at lower temperatures compared to conventional methods, resulting in reduced energy consumption, lower greenhouse gas emissions, and improved workability. By incorporating additives or technologies that enable mixing and compaction at reduced temperatures, WMA is used to achieve one or combination of the following benefits:

- Extending the paving season (late season paving)
- Reducing GHG emissions during production
- Reducing energy consumption during production
- Enhancing compaction

In Ontario, an estimated 26% of the municipalities use WMA in their paving operations. A breakdown based on geographical zone is presented in Figure-6. Out of the 26% that use WMA, 14% use it year-round and 12% allow it only after a prescribed date. It is also worth noting that the municipalities that are currently not using it have mostly reported that they are either considering it for future projects, or they deal with it on project-by-project bases during the design phase. A total of 353,908 tonnes of WMA is projected to be used in the 2024 construction season by Ontario municipalities. A breakdown of the total 2024 WMA tonnage is also presented in Figure-6.

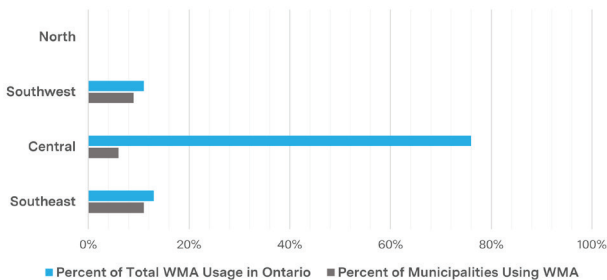


Figure 6 - Geographical Breakdown of Municipalities using WMA and the Total 2024 WMA Tonnage

### In-Place Recycling (HIR/CIR)

In-place recycling, encompassing Hot In-Place Recycling (HIR) and Cold In-Place Recycling (CIR), represents a sustainable and cost-effective approach to rehabilitating municipal roads while minimizing environmental impact. HIR involves heating the existing pavement surface, rejuvenating it, and then reprocessing it in situ, while CIR involves milling the existing pavement, adding recycling agents, and repaving the material back onto the road surface without heating. Both methods offer significant advantages over traditional road rehabilitation techniques, including reduced material consumption, shorter construction times, reduced excess soils generation, and improved pavement performance of existing structure. In-place recycling techniques have gained popularity among municipal authorities seeking efficient and eco-friendly solutions for maintaining and upgrading their road networks.

A total of 610 Kilometers of road is expected to be treated with HIR or CIR by municipalities in Ontario during the 2024 construction season. A breakdown of the number of municipalities using in-place recycling as well as the breakdown of the total HIR/CIR Kilometers is presented in Figure-7. It is worth noting that 33% of the municipalities in the 2024 survey are expecting to use HIR or CIR during the 2024 construction season.

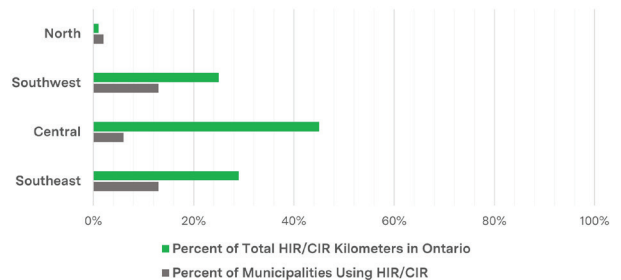


Figure 7- Geographical Breakdown of Municipalities using HIR/ CIR and the Total 2024 HIR/CIR Kilometers



## Municipal RAP Specifications

Through the GR/OAPC Municipal Paving Forecast survey total of 185 municipalities' responses were analyzed and resulted in a better understanding of municipal specification of RAP across Ontario. According to our data, 71% of the municipalities have indicated that their specifications allow the use of RAP in the HMA layers in their paving projects. The geographical breakdown of this data is presented in Figure 8, showing that RAP intake is closely equally popular across Ontario with exception of the North geo-zone. The collected data also showed that at least 7 municipalities have moved from Not-Allowing RAP to Allowing the use of RAP in their specification language in the past five years. Figure-9 demonstrates the distribution of pavement recycling technologies implementation in Ontario municipalities.

## RAP Stockpile Management (Industry and Municipalities)

It is common knowledge that the most significant reason behind limiting the use of RAP in new asphalt concrete mixes is material variability (variability in RAP aggregate gradation and characteristics, as well as variability in RAP asphalt content and characteristics). Since RAP is usually reclaimed from different sources with different material characteristics and reclamation methods, it is vital to focus

on achieving homogenous stockpiles by applying best practices in managing and processing. The following paragraphs present information on the current state of practice with RAP management which was collected as part of the 2021 Ontario RAP Survey, conducted by GR, OAPC, and MEA.

Decisions made at the beginning of the RAP stockpiling and processing activity play a significant role in creating a quality homogeneous RAP product for use in HMA for road construction. Figure 10 shows how facilities manage their stockpiles and whether they are putting all incoming RAP materials in one pile or creating separate stockpiles for RAP coming from different sources. It is found that most municipalities use a single stockpile for their collected RAP. The reason is that these municipalities only collect RAP millings from their own roads or millings from adjacent provincial roadways. The similarity in material justifies the decision to hold only single stockpiles for all collected RAP in this situation. Multiple factors are considered when making the decision on whether to collect RAP in single or multiple stockpiles. Table 5 provides description of these decision factors. It is common practice for Ontario contractors/HMA producers to inspect incoming RAP for potential contamination as shown in Figure 11. Another common way for guaranteeing clean RAP is accepting incoming RAP based on pre-approved contractors, given that the contractor has clear instructions on the expected quality of collected RAP.

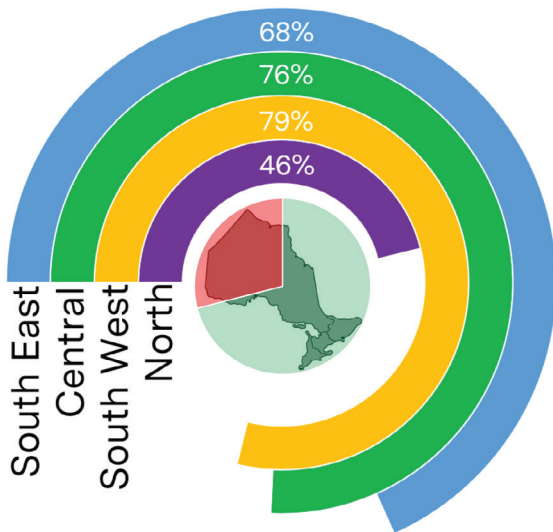


Figure 8 - Municipal Specs on RAP Use in Ontario (Percentage refers to municipalities that allow the use of RAP in their specifications).

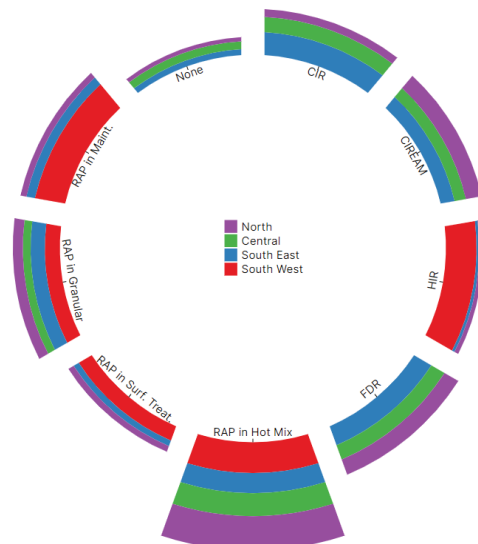


Figure 9- RAP and Pavement Recycling Technologies Implementation in Ontario

Factor	Comments
Availability of space	Based on the Ontario RAP Survey, RAP stockpiles take an average space of 600m <sup>2</sup> in Municipal yards and 4000m <sup>2</sup> in contractors/HMA production facility.
Municipal QA Specs	Facilities serving multiple Municipalities may need to have multiple stockpiles if one or more Municipalities require that RAP be from Classified or Captive stockpiles to be accepted in their projects which may be challenging with limited space especially in the Greater Toronto Area.
Contaminated RAP	If it happened that the facility accepted RAP that was likely to be contaminated (soil, vegetation, geosynthetics), it is common practice that contaminated RAP be kept in a separate stockpile and used only in road bases or shoulders. Contaminated RAP is not fit to be included in new asphalt mix production.
Consistency of Source	If large quantities of RAP are being brought from a single project or jurisdiction (specially if it is reclaimed through milling), it is most cost-effective to keep it in a separate stockpile as processing efforts on this would be minimal as it is highly probable that the material would be very consistent.

Table 5 - Decision Factors on Number of RAP Stockpiles in a Facility

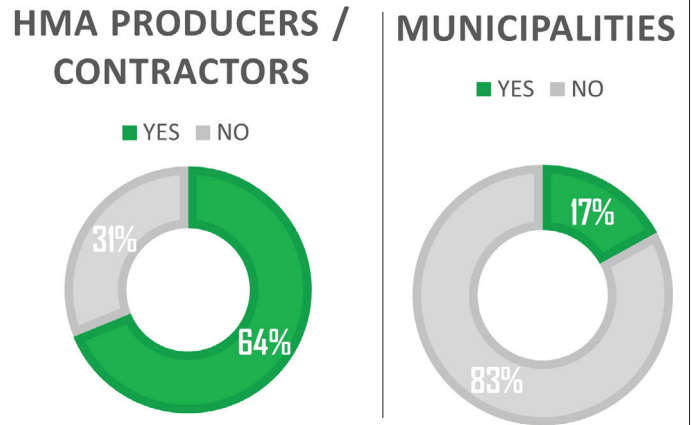


Figure 10 - 2020 Ontario RAP Survey - Do you Separate RAP Based on Source?

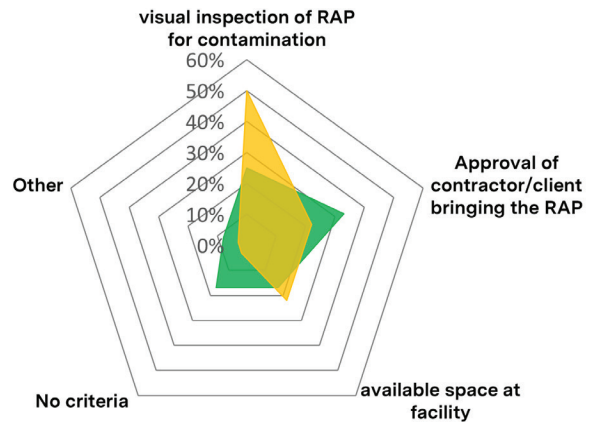


Figure 11 - Incoming RAP Quality Inspection at Municipal and HMA Producers / Contractors Facilities

## RAP Processing (Industry and Municipalities)

RAP is usually reclaimed from different sources with different material characteristics. The main objective of processing RAP is to limit variability and create a uniform and homogeneous stockpile through breaking apart agglomeration of RAP particles, reducing maximum aggregate size as desired, and screening RAP piles into different sizes for more controlled mix design. During the processing operation, there are key precautions that can significantly affect the quality of the RAP. Figure 12 provides a bigger picture of what precautions are taken by Ontario municipalities and private sector facilities when processing RAP. The only two responses by municipalities were “Stockpiling unprocessed RAP into layers” and “N/A”. This can be explained that RAP in most municipal yards is collected through millings from road projects built by the same municipality under similar material specifications, therefore it requires less separation of stockpiles (Figure 10) and less processing efforts.

To reduce material variability and achieve the main objectives of the RAP processing operation, there are multiple options that are available in the industry. RAP processing can be achieved through crushing, mixing, screening, or fractionation. Figure 13 shows the Ontario state of the practice in RAP processing as collected from the 2020 Ontario RAP Survey. One observation that can be concluded by looking at the Municipal data in Figure 13 is that RAP collected by Municipalities is usually pavement millings that comes from consistent projects constructed under similar specifications and therefore it would require minimum processing and stockpile separation efforts to maintain minimum material variability. Choosing the appropriate one or combination of processing methods depends on the following factors:

- Availability of tools and equipment
- Type of RAP available at a certain facility (milling, demolished pavement, Unknown Composition stockpiles).
- Agency specifications
- Desired RAP gradation properties

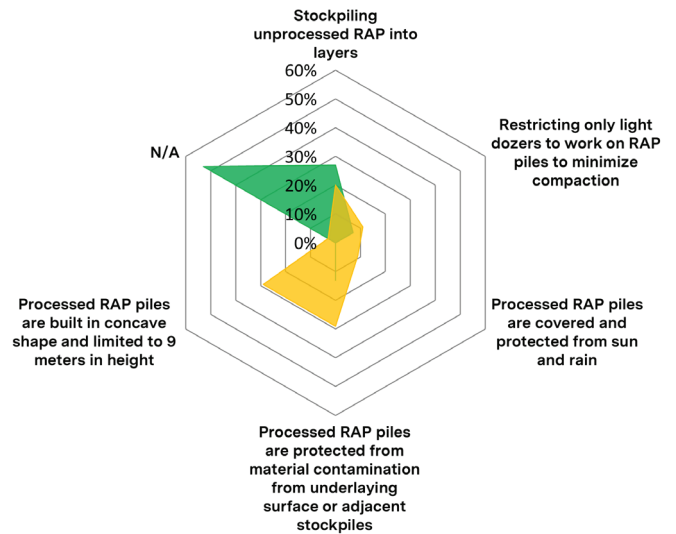


Figure 12 – RAP Processing Operational Precautions in Ontario

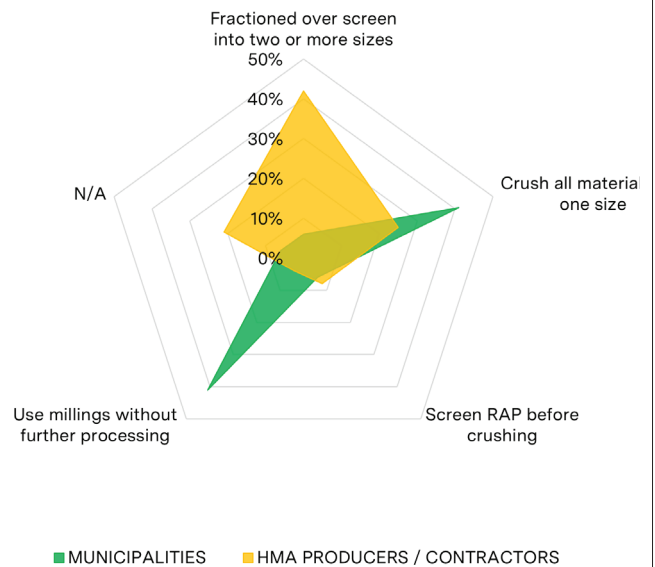


Figure 13- RAP Processing Methods in Ontario

High variability of the RAP is commonly known as one of the major hinderances for incorporating higher amounts of RAP in production of new hot and warm mix asphalts. Akin to many other areas, addressing an issue at its source can render considerable economic and engineering benefits as compared to post-treatment of the symptoms. Improving the RAP management strategies in the following aspects can, therefore, contribute to lowering the variability of the RAP and improving the quality of incorporated mixes.

## Stockpiling

### Methods (Truck & Loader vs. Stacking Conveyor)

- **Ensuring Safety While Using Truck & Loader Method:** With traditional truck stockpiling methods for RAP, it is recommended that the small berms be formed on the stockpile paths at the upper perimeter to the height of the [truck] axle to mitigate accidents of trucks rolling over on top of stockpiles. The truck and loader method usually used for stockpiling unprocessed RAP.
- **Improve Work Efficiency Through Stacking Conveyor:** It is highly recommended that incoming RAP millings or processed RAP be stockpiled through a stacking conveyor. Use of crushing or screening plants with discharge conveyors systems present opportunities for increasing safety, and increasing the possible stockpile size, while reducing time and cost of stockpiling RAP. However, there are some considerations that need to be taken in consideration to prevent material segregation.

### Protect from contamination

- **Paved Ground Surface**  
Having a paved surface under the stockpiles helps prevent contamination and sinking, and to assist in drainage. OPSS.MUNI.1150 requires that the surface under RAP stockpiles be paved or be constructed of compacted aggregates to limit contamination.
- **Avoid Using The Bottom Of The Stockpile**  
OPSS.MUNI.1150 requires that the bottom 0.3m of a RAP stockpile shall not be used if the sub-surface is not paved to avoid contaminating the mix.

### Minimize Trapped Moisture

RAP holds water and does not drain as well as an aggregate stockpile, so efforts should be made to handle and store RAP in such a way as to minimize moisture content. Trapped moisture in RAP can cause the plant fuel consumption to significantly increase during production. Trapped moisture can also alter the true weight of materials going through the cold feeds and eventually affect the AC content in the final mix in continuous mixing plants. In batch plants, trapped moisture will affect the amount of mixing required to remove the moisture from RAP increasing energy consumption.

- **Stockpile Orientation:**  
The sun is a big radiant heater. Meeker Equipment Co. Inc. found through their operations that they could reduce the stockpiles moisture content by half with

managing the orientation of the stockpile with respect to the sun, resulting in an overall fuel cost savings of 6-12%. - SOURCE

- **Pave & Slope:**
  - OPSS.MUNI.1150 requires that the surface under RAP stockpiles be sloped at a minimum of 3% to facilitate drainage and thus reducing drying time and cost during mix production. When moisture is present in the RAP source, it will naturally take more thermal energy to remove this variable which causes strain on an asphalt plant producing the asphalt mix.
  - OPSS.MUNI.1150 also requires the surface under the stockpile to be either paved or compacted granular pad.
  - According to Simmons, 1996, a 4ft slope in a 75' wide RAP stockpile would lead to a decrease in moisture content by 2.1% between the front and the sloped back of the stockpile.

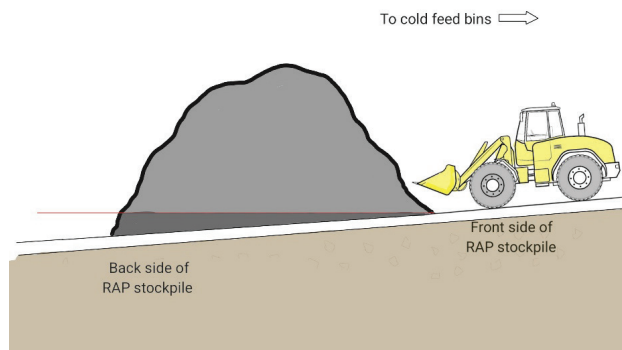


Figure 14- Managing Stockpile Moisture Through Sloping and Paving the Ground Surface

Material Type	Front Side Ground Level	Front Side 4' Level	Back Side Ground Level	Back Side 4' Level	Avg. Moisture Use Level
Sand	5.6%	5.2%	23.3%	5.8%	5.4%
Screening	7.0%	6.0%	14.0%	7.2%	6.5%
No. 78	1.4%	-	4.4%	-	1.4%
No. 67	0.5%	-	1.5%	-	0.8%
No. 5	-	-	-	-	-
RAP (-1/2")	5.7%	5.6%	9.6%	5.7%	5.7

Table 6- Moisture in Stockpiles from HMA Plant in NC, USA (Simmons, 1996)

### Small Individual Stockpiles:

Having separate daily processed RAP stockpiles in an order that allows the oldest RAP stockpiles brought from extraction to be put through the asphalt plant first, would help stockpiles to dry more efficiently than if they were combined.

### Protection From Rain

- Although more costly, covering the stockpiles where rain is very prevalent. Nevertheless, air circulation should not be prevented therefore, directly covering with plastic tarp is not recommended.

- According to J. Don Brock, 2007, the cost of building cover structure for processed stockpiles would be paid back within 2.6 years due to increased production rates observed from lower moisture levels in the stockpiled materials.

### Advantages Of Having Low Moisture:

- According to J. Don Brock, 2007, the fuel consumption for drum mixers would decrease by 25% for aggregates and RAP that has 6% moisture compared to one having 9% moisture. "A 1% decrease in moisture in your stockpile decreases your costs by 12% because your dryer doesn't have to work as hard," Bill Garrett director of training at Meeker Equipment says. [SOURCE](#)

- In addition to the benefit of decreasing fuel consumption, a decreased moisture content in stockpiles lead to higher production rates. According to Simmons, 1996, an overall increase in production rate of 83 tonnes per hour for Double Borell mixer plants and 80 tonnes per hour for Counterflow Dryer mixer are observed when the ground below the stockpile is paved and sloped.

- Managing RAP source moisture is a very important step in producing a consistent RAP material for the asphalt plant and field operations. A variable amount of moisture in materials going through the cold feeds can affect the AC content in the final mix in continuous mixing plants.

### Minimize compaction

#### - Protect From Rain:

Compaction due to rain can be avoided if the producer has a protective structure over the stockpiles.

#### - Protect From Heavy Equipment

- Using scrapers or trucks (truck & loader stockpiling) compacts the stockpile with every lift, which is not desired.

- When economically feasible, using stacking or radial conveyors reduces compaction while increasing productivity, stockpile capacity, and safety.

#### - Adverse Effects Of Stockpile Compaction:

Compaction in the stockpile by any cause can affect materials costs. If a stockpile is 45 percent compacted, that same percentage is expected to be subtracted from any profit - [SOURCE](#)

### Minimize Segregation

#### - Adverse Effects Of Material Segregation

Segregation occurs when different-sized particles separate, leading to inconsistencies in the mix composition. This can result in uneven distribution of aggregates and binder, compromising the structural integrity and durability of the pavement.

#### - Mitigation Through Stacking Conveyor Systems

- When a variable height stacking conveyor is used, it should be set so that the drop point is as low as

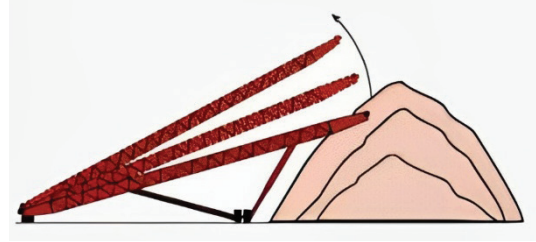


Figure 15- Variable Height Conveyor Best Practice Segregation (Jerry Nohl, 2000)

possible, and then raised as the stockpile is built.

- The use of radial stacking conveyors can also limit segregation in the body of the pile by minimizing the amount of segregated course materials on the sides of the pile when the conveyor moves radially left

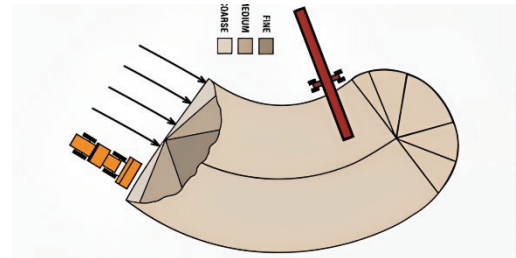
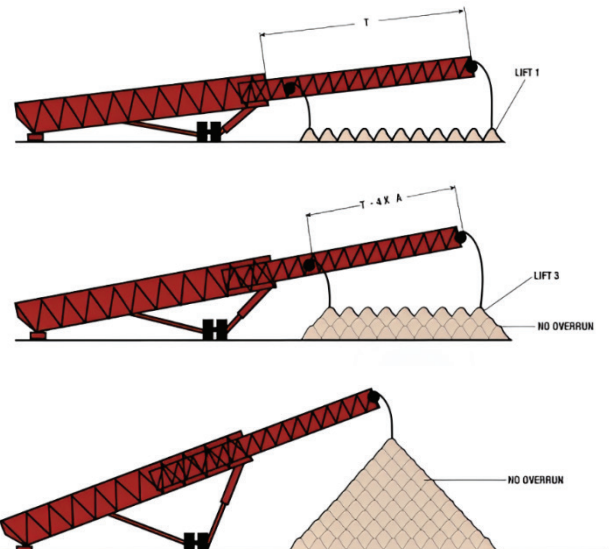


Figure 16- Radial Stacking Conveyor Limits Segregation (Jerry Nohl, 2000)

and right. However, the external most sides of the stockpile will still be subject to segregation.

- Telescoping conveyor systems offer better results in limiting material segregation by building a stockpile through creating many small windrows. The



segregation pattern in each small windrow will be repeated throughout the larger stockpile, leading to a more overall blending of materials.

### Other Stockpiling Considerations

- **Strategically placing the stockpiles between the plant and concerned neighbors presents a sound barrier to keep the noise of daily operations from drifting into new neighborhoods.**
- **Many producers elect to place their least-used materials furthest from the plant and closest to the edge of their property in an effort to cut down on equipment-operation noise.**
- **By planning the placement of material piles, aggregate suppliers and plant owners would have the opportunity to map out where stockpiles will be in relation to power lines as well.**
- **It is recommended to have a clearance of at least 10 feet from the apex of the stockpile and live power lines. [SOURCE](#)**
- **By pre-planning areas for RAP stockpiles, the facility manager can provide signage that eliminates confusion for loader and haul truck operators bringing in incoming RAP. This helps prevent material contamination.**
- **It is advantageous to collect and record material information on the RAP being collected/milled.**
  - Type of Grinding, resurfacing, full depth etc.
  - Excavation of Roadways, Parking lots, Driveways, Etc.

For example, milling from resurfacing jobs could be FC2, FC1, 12.5 Superpave, HL3HS, HL3, etc. which all have higher AC contents, while full depth Grinding could have Surface Course mixes and Base course mixes blended together. Plants are encouraged to separate these piles if there is enough land space to accomplish this.

## Processing & Crushing

### Screening before crushing

- **Limiting Dust ( $P_{200}$ )**
  - It is important to select the top size for the crushing operation. It is popular to select a top size so that the crushed RAP can be used in any type of mix. However, crushing to smaller top sizes will increase the dust content (percentage passing the No. 200 sieve) in RAP, which can limit how much RAP can be used in new mix designs while meeting criteria such as VMA and dust-to-binder ratio.
  - Since crushing RAP into smaller sizes will create significant amounts of dust, screening RAP before it enters any crushing equipment will allow the finer RAP particles which pass through the screen to bypass the crushing process.
  - When you process large amounts of RAP millings with a lot of fines, a mobile screen helps to reduce wear costs and increase total production
- **Increasing Efficiency**

- It is important to screen off and remove fines prior to the crushing process to protect the wear parts from getting chewed up quickly, which affects maintenance and operations costs. In this case, the additional investment of a scalping screen can pay for itself.

### [SOURCE](#)

- In cases where there is need for large amounts of small-finished products such as ½-inch minus material, the onboard screen of a closed-circuit impact crusher might not have enough capacity and can become a bottleneck. In this case, a screening plant after the impact crusher helps again to increase production and lower wear costs.
- The smaller the infeed or the finished products get, the more screening capacity will be needed.

### Fractionation

- RAP fractionation is basically the process of separating RAP based on top size to reduce variability and limit crushing effort as well as dust generated from un-necessary crushing.
- To address material variability, many jurisdictions have been using fractionating practices for RAP from similar sources, to separate the stream into fine and coarse fractions, acknowledging that different fractions can have different mobilized AC contribution (Saliani et., al., 2019). This will help with lowering the variability of the final mix production, especially with respect to the binder content tolerances.

### Benefits of Fractionation

- Limiting dust generation from excess crushing
- Allows for more control on the RAP blend to meet volumetrics in different mix designs.
- Reduces variabilities in stockpiles and provides increased consistency within each fraction
  - Coarse fractions contain a lower asphalt cement content while fine fractions have higher AC contents.
  - Reduces the potential for segregation of the RAP which can impact asphalt cement content.

### Processing of millings

- **Considerations During The Milling Process:**
  - The nature of milling processes can affect the contamination in the reclaimed asphalt pavements. To this end, the milling processed should be well controlled to avoid introduction of any deleterious materials during the process.
  - During milling operations, managing extraction speeds and water control can prevent the addition of excess water in the RAP source.
  - The milling operation should be closely monitored and examined to ensure that the milled material is not contaminated with soil, geosynthetics, or other debris.
  - The truck loads should always be inspected upon arrival at the storage facilities for any deleterious materials resulting from excessive milling depth.
  - Milled RAP that is found to be contaminated, should not be used in Hot-Mix paving.
- **Limiting Dust ( $P_{200}$ )**
  - It is recommended to limit any further crushing for

milled RAP to limit further generation of dust. Milled RAP already contains significant amounts of dust (P200) due to the grinding and milling operations.

- Screening and Fractionating milled RAP into two piles of coarser than typical NMAS and finer than typical NMAS is a good practice to limit further crushing and dust generation. It also allows for utilizing the milled RAP into HMA with least processing cost and effort.

- **Millings From Multiple Sources**

- Blending of material during processing operations is key to achieving consistent stockpile from multiple RAP sources.

- A bulldozer, excavator, or similar equipment are good equipment to be used to blend materials from different locations in the multiple-source RAP stockpile as it is fed into the screening and crushing operation to limit variability.

- It is important to screen the milling products and break down the RAP agglomerations and scalping too large particles before introducing the RAP materials into a new mix production. Typically, this is achieved by postprocessing the millings in a separate space and before moving it to the stockpile, which also creates an additional opportunity of blending the processed millings to achieve better homogeneity in the stockpile and avoid segregation (Rathore et. al., 2021).

## RAP Crushing

- **Crusher Types**

- Horizontal Shaft Impact Crushers are found to be the tool of choice for processing RAP, as it works by breaking down agglomerations of RAP while maintaining the aggregate gradation.

- Issues With Using Inappropriate Crusher:

- Using other types of crushers (such as Jaw or Cone crushers) to process RAP could result in crushing and splitting aggregates and altering the gradation. In addition to generating an excessive amount of dust materials.

- Using Cone crushers would repeatedly crush RAP particles to break it apart resulting in stripping the asphalt coating from the RAP creating white rock which will need additional asphalt to coat it when used in hot mix.

- The excess heat generated from using a Cone crusher to break down RAP can cause the RAP to harden and increase the stresses on the crusher's bearings which could lead to extensive maintenance.

- **Reducing Maintenance Needs**

- Avoid crushing and screening RAP that is wet or that has absorbed a lot of heat. When the RAP is wet or hot it would become stickier and would tend to build up on screen equipment, conveyor belts and clogs crushers which leads to additional equipment maintenance.

- It is important to screen off and remove RAP fines prior to the crushing process to protect the wear parts from getting chewed up quickly

## Sampling & Testing

The properties of crushed RAP in the stockpile must be precisely known for it to be used as a component in a new asphalt mix. Material variability such as under/overestimation of the binder contribution or degree of blending can lead to premature distresses in the RAP incorporated paved mix. Determining if the RAP processing provides a consistent material over time requires regular testing and analysis of the RAP to ensure the stockpile variability is within the acceptable limits. The following is the recommended QC on RAP piles according to NCHRP Report 752 and OPSS.MUNI.1003:

### Recommended Tests

- Gradation Test of Recovered Aggregates (Sieve Analysis)

AASHTO T 30

- Consensus Properties of Recovered Aggregates

AASHTO T 176, LS-629, ASTM D 4791, and ASTM D 5821

- Bulk Specific Gravity of Recovered Aggregates

AASHTO T 84 and T 85

- Asphalt Cement Content (AC%)

AASHTO T 164 or AASHTO T 308

- Recovered Binder Properties (PG Grading)

AASHTO T 319 or ASTM D5404 and AASHTO R 29

### Sampling Frequency

- For each stockpile, it is recommended that at least 10 samples be collected to calculate the variability statistics (Mean, Standard Deviation) of the material properties test results.
- When more material is added to the stockpile, it is recommended that minimum sampling and testing be conducted every 1,000 tons of added materials. With a minimum of 10 samples.
- For Recovered Binder testing, the testing is recommended every 5,000 tons with one specimen.
- For the Bulk Specific Gravity, the testing is recommended every 3,000 with a sample of 3 specimens.

### Sampling Procedure

- It is recommended that samples be taken as the stockpile is being built to provide representation of the entire stockpile.
- Samples from different stockpiles should not be combined as the test results for each sample should reflect the existing variability statistics.
- Obtaining samples of existing sitting stockpiles should be done according to AASHTO T2(section X1.2) or ASTM D-75.03

### Recommended Minimum Variability

- The recommended maximum standard deviation for a set of 10 samples is as follows:
  - 0.5% for AC Content;
  - 5% for Gradation on all sieves and 1.5% for the P200; and
  - 0.03 for Specific Gravity.

Mneina, Amin. "Ontario Municipal Paving Forecast." OGRA Milestones Magazine, Volume-22, No. 2. May 2021, pp.9. URL: <https://online.fliphtml5.com/jgfei/djqz/>

Mneina & Smith, Promoting Sustainability in Infrastructure Through Quantifying Reclaimed Asphalt Pavement – An Ontario Municipal Case Study, Transportation Association of Canada, Halifax, NS, 2019.

Clark, W. A. V, Angeles, L., Conti, E. A., Transportation, S., Dot, N. C., Hammond, P. J., & Dot, W. S. (1978). Recycling Materials for Highways, National Cooperative Highway Research Program Synthesis of Highway Practice No. 54. Washington, DC.

McLuckie, R. F., Korgemagi, P., & Villneff, H. C. (1987). Performance of High Ratio Recycled Pavements in Northern Ontario. In 32nd Annual Conference of the Canadian Technical Asphalt Association (pp. 42–72). POLYSCIENCE PUBLICATIONS INC.

EBA Engineering Consultants Ltd. (2013). Aggregate Supply and Demand Analysis. Report No. K23103029-01-001

Williams, B. A., Copeland, A., & Ross, T. C. (2018). Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: Information Series 138-NAPA, 46. <https://doi.org/10.1016/j.ydbio.2005.08.010>

Ministry of Natural Resources Ontario. (2010). State of the Aggregate Resource in Ontario Study.

Copeland A 2011 "Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice," Fed. Hwy. Adm., no. FHWA-HRT-11-021

Tavassoti-Kheiry, P., Solaimanian, M., & Qiu, T. (2016). Characterization of high RAP/RAS asphalt mixtures using resonant column tests. *Journal of Materials in Civil Engineering*, 28(11), 04016143.

Rathore, M., Haritonovs, V., & Zaumanis, M. (2021, November). A Critical Review on Mixing Parameters For High Content Reclaimed Asphalt Mixtures. In IOP Conference Series: Materials Science and Engineering (Vol. 1202, No. 1, p. 012025). IOP Publishing.

Saliani, S. S., Carter, A., Baaj, H., & Tavassoti, P. (2019). Characterization of asphalt mixtures produced with coarse and fine recycled asphalt particles. *Infrastructures*, 4(4), 67.

National Academies of Sciences, Engineering, and Medicine 2013. Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content. Washington, DC: The National Academies Press. <https://doi.org/10.17226/22554>.

Jerry Nohl, B. D. (2000). Technical Paper T-551 Stockpile Segregation. Morris, MN: Superior Industries.

J. Don Brock, N. F. (2007). Technical Paper T-126 Productivity. Chattanooga, TN: ASTEC Inc.

Simmons, G. H. (1996). Technical Paper T-129 Stockpiles. Chattanooga, TN: ASTEC Inc.



A special thank you to all private sector companies that provided feedback and valuable input in the data collection and creation of this report



Municipalities Consistently Supporting the Municipal Paving Forecast Since 2018



Municipalities Consistently Supporting the Municipal Paving Forecast for the Past 5 Years

