2023 Ontario Reclaimed Asphalt Pavements (RAP) Report

Good Roads

in association with

CPATT
CENTRE FOR PAVEMENT AND TRANSPORTATION TECHNOLOGY

MUNICIPAL ENGINEERS ASSOCIATION

apc
ONTARIO ASPHALT PAVEMENT COUNCIL

Message from stakeholders

Good Roads recognized the need to obtain accurate data on Reclaimed Asphalt Pavements (RAP) quantities and locations in Ontario to be able to better monitor and evaluate the effects of current practices and specification on the lifecycle of RAP. The initiative started in 2019 with 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), and the Centre for Pavement and Transportation Technology (CPATT) at the University of Waterloo to quantify the amounts and identify best practices of RAP stockpiling in Ontario.

Report Objectives

- Document the historical background of RAP use in Ontario
- Report vital metrics on RAP stockpiling inventory in Ontario
- Present an Ontario municipal state of the practice on RAP
- 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, 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

Ontario RAP Inventory

In this study, Ontario was divided into four geographical zones (Northern, Southeast, Southwest, and Central) as presented in Figure 1. On average, the study collects data from 50 facilities each year.

Table 1 presents a summary of facilities containing RAP in each geographical zone and their total reported unprocessed RAP inventory per year. The RAP quantities in Table 1 do not include RAP that is stockpiled in municipal facilities. In 2020, it was found that RAP 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 by investigating historical satellite images. In the 2020 survey, producers also reported a surplus of generated RAP being as high as 50% in some facilities in the Central zone.

Mneina & Smith,2019 estimated the amount of processed RAP as well as the amount of RAP in locations with poor image quality and were able to report a total estimate of 6.7M tonnes of RAP in Ontario for 2019. Figure 2 presents the magnitude of the 2019 RAP quantity in terms of potential environmental, social, and economic benefits.

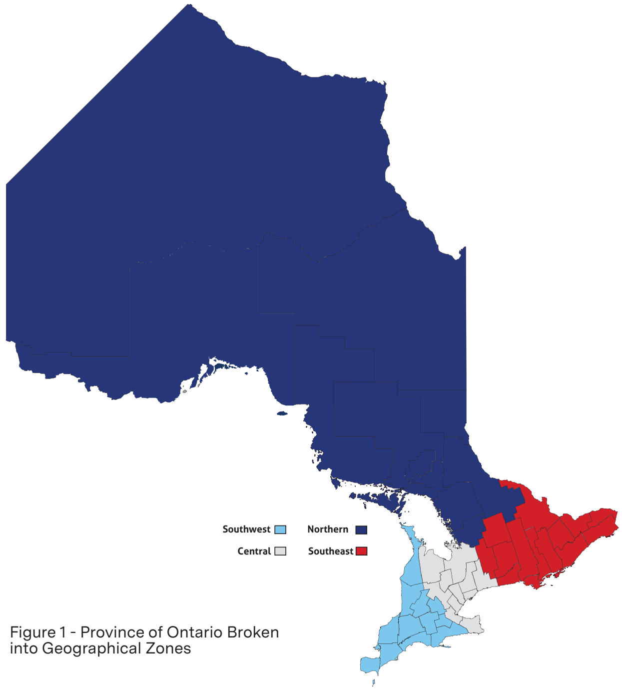

Figure 1 - Province of Ontario Broken into Geographical Zones

Year	2019		2020		2021		2022	
Geo-Zone	Facilities Scanned	Unprocessed RAP (Tonnes)	Facilities Scanned	Unprocessed RAP (Tonnes)	Facilities Scanned	Unprocessed RAP (Tonnes)	Facilities Scanned	Unprocessed RAP (Tonnes)
North	5	868, 418	5	299,00	4	27,500	7	229,993
SouthWest	7	263, 007	4	287, 296	7	370, 269	7	413,435
Central	37	1, 901, 174	21	1, 434, 510	32	1, 815, 253	29	1,839,396
SouthEast	8	1, 280, 015	9	260, 000	17	739, 899	17	791,342
TOTAL	57	4, 312, 614	39	2, 280, 806	60	2, 952, 920	60	3,274,166

Table 1 - Unprocessed RAP Quantities in Ontario

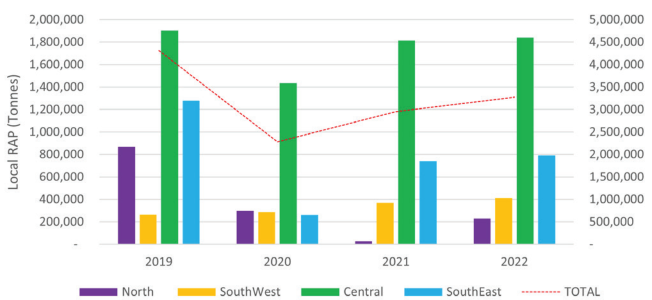

Figure 2 - Annual Reported RAP Quantities

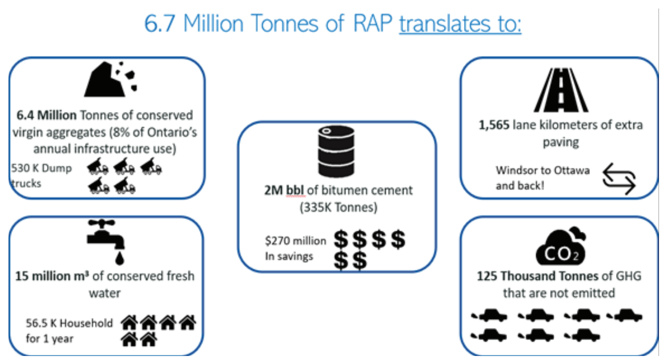

Figure 3 - 2019 RAP Quantities in Ontario Presented Based on its Sustainable Value.

Municipal Consumption of Mix Asphalt and RAP

Availability of information on local quantities and practices of Mix Asphalt paving is a key resource in the continuous improvement and growth of this industry's stakeholders. The GR/OAPC Municipal HMA Liaison Committee was able to bridge the gap and establish an ongoing study to collect and share such vital information through the Municipal Paving Forecast annual survey. Since 2016, Municipalities across Ontario have been invited to provide information on their local paving quantities and practices in a survey created by the Municipal HMA Liaison Committee and administered by GR.

2.1 Municipal Asphalt Paving Tonnage

A summary of the HMA paving quantities per year are presented in Table 2. The quantities are summarized as per geographical zones. It is noted that the Central Zone had always accounted for most of the paving tonnage with an average annual share of 54% from the total HMA tonnage.

Through extrapolation from the Municipal Paving Forecast surveys 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

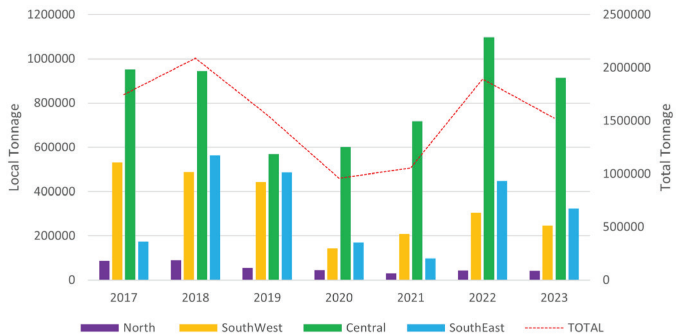

Figure 4 - Annual Reported Municipal HMA Paving Tonnage

Municipal HMA Paving (Tonnes)

Year	North	SouthWest	Central	SouthEast	TOTAL
2017	87400	531289	952400	174836	1, 745, 925
2018	90300	487810	944905	564807	2,087,822
2019	54446	443525	569815	486765	1,554,551
2020	44925	143680	601915	169341	959,861
2021	30100	207988	718399	97453	1,053,940
2022	44150	303530	1097509	448105	1,893,294

Table 2 - Municipal Hot-Mix Paving Quantities in Ontario

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believes that MTO is the largest user of HMA at 2.5-3M tonnes/year. In the past seven years the paving average represented the following percentages for each geo-zone: [N=4%, SW=22%, C=54%, SE=20%].

2.2 Municipal RAP Consumption Tonnage

Estimating the municipal RAP consumption was made using survey results, assumptions, and simple calculations. Through the 2023 Municipal Paving Forecast 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 64 municipalities. Although this estimate represents only 64 out of 444 municipalities, it is considered an accurate estimation as these 64 municipalities represent 82% 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 2023 RAP consumption locations and quantities alongside the RAP inventory locations and quantities.

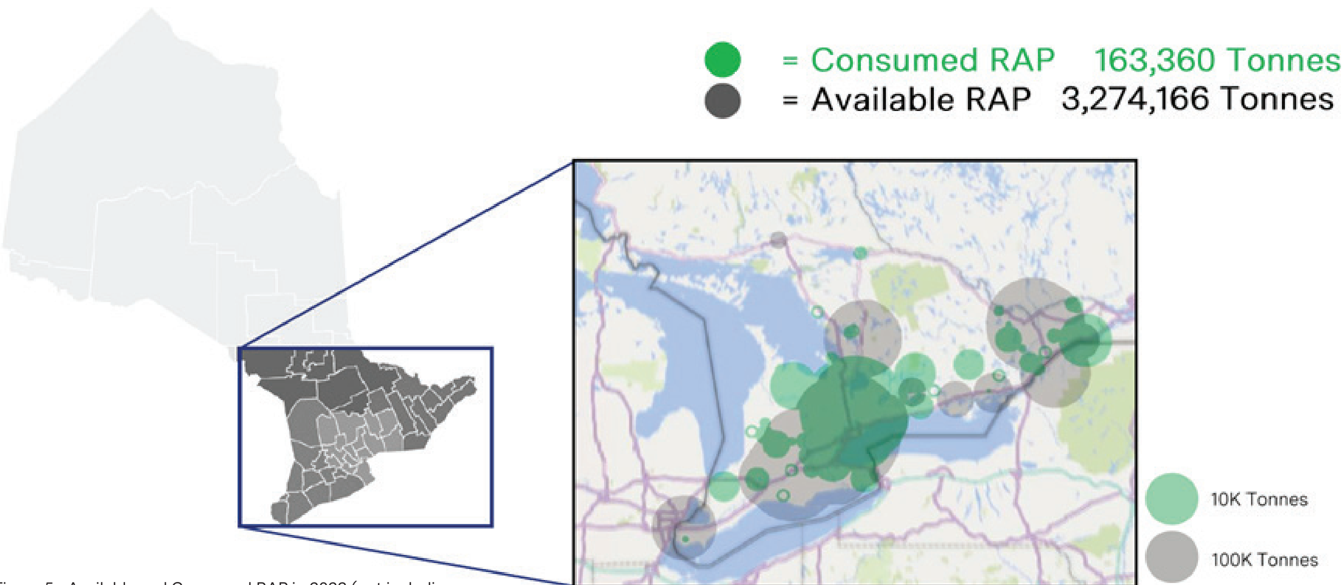

Figure 5 - Available and Consumed RAP in 2023 (not including MTO's consumption)

Geo-Zone:	North	SouthWest	Central	SouthEast
RAP Consumed: (Tonnes)	4,000	22,000	104,000	33,000

Table 3 - Municipal Consumed RAP in Ontario in 2023

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Municipal RAP Specifications

Through the GR/OAPC Municipal Paving Forecast survey we analyzed a sample population of 158 municipalities and got a big picture of municipal use of RAP across Ontario. According to our data, 66% 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 4, 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 5 municipalities have moved from Not-Allowing RAP to Allowing the use of RAP in their specification language in the past three years.

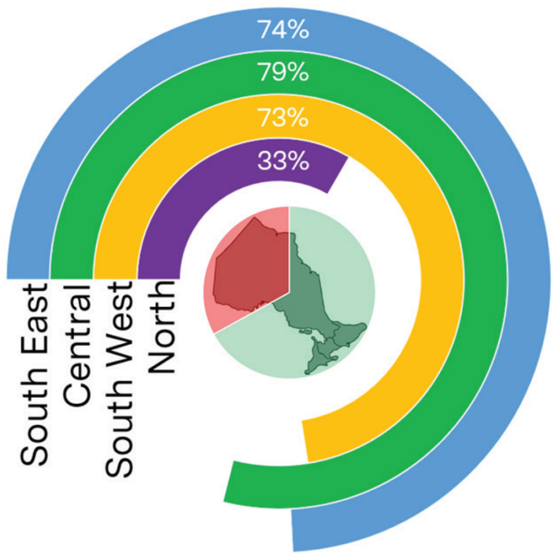

Figure 4 -Municipal Specs on RAP Use in Ontario (Percentage refers to municipalities that allow the use of RAP in their specifications).

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 were 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 6 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 majority of municipalities use a single stockpile for their collected RAP and the reason behind that is most municipalities reported that they only collect RAP millings from their own roads or milling from adjacent MTO roads. The similarity in material justifies the decision of holding only single stockpiles for all collected RAP in this situation. Multiple factors are considered when making the decision on whether to collect RAP in a single or multiple stockpiles. Table 3 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 7. Another common way in 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.

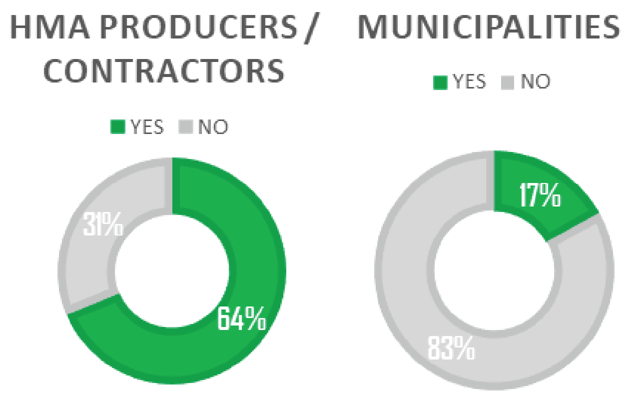

Figure 6 - 2020 Ontario RAP Survey - Do you Separate RAP Based on Source?

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Factor	Comments
Availability of space	Based on the Ontario RAP Survey, RAP stockpiles take an average space of 600m² in Municipal yards and 4000m² 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 4 - Decision Factors on Number of RAP Stockpiles in a Facility

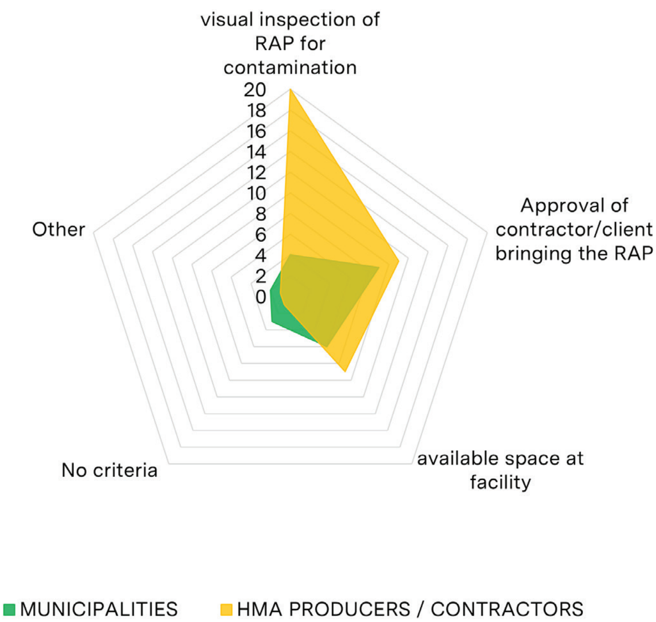

Figure 7 - Incoming RAP Quality Inspection at Municipal and HMA Producers / Contractors Facilities

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 8 provides a bigger picture of what precautions are taken by Ontario municipalities and private sector 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 6) 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 9 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 9 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. Choosing the appropriate one or appropriate 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

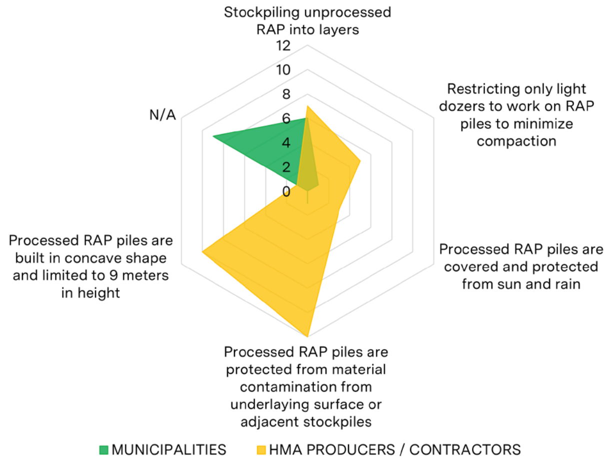

Figure 8 – RAP Processing Operational Precautions in Ontario

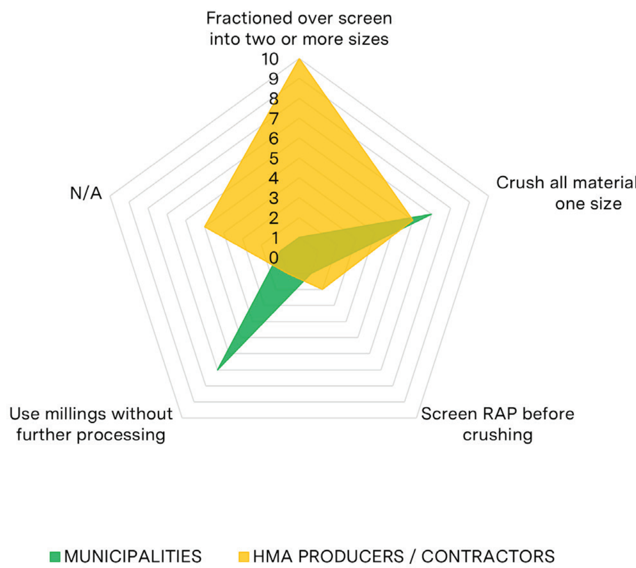

Figure 9

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. Radial Stacking Conveyor)

- **Ensuring Safety While Using Truck & Loader Method:**
  With traditional truck stockpiling methods, 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.

- **Improve Work Efficiency Through Stacking Conveyors:**
  Use of crushing or screening plants with discharge conveyors, or automated conveyor systems, present options for producers looking for a way to reduce the time spent on building berms and worrying about rollover accidents compared to traditional stockpile building methods.

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.

- **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.

- **Advantages Of Having Low 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

  • 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 segregation and 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

Tracking of quantities

- **Inventory Analysis**
  Conducting annual inventory analysis would provide your facility with the needed information to plan for upcoming project and optimize use of space at your facility. Keeping periodic records of the following metrics is recommended for a facility that holds RAP stockpiles:
  • Quantity of RAP in hand (Ready to Use RAP vs.

Unprocessed RAP);

- Quantity of RAP received per year;
- Quantity of RAP used per year (Mix Production by Mix Type)
- Quantity of RAP surplus/shortage each year.

– **Stockpile Quantities**

- Since space is limited at many facilities and yards, establishing a relationship between incoming material quantity and the resulting stockpile area is key in optimizing space at your yard. By knowing the desired RAP stockpile capacity, you can estimate the resulting stockpile base area as is a factor of:
  - Conveyor Length;
  - Angle of Inclination of the conveyor;
  - Angle of Repose (material property ~35 degrees for crushed RAP); and
  - Material Density (~720Kg/m3).
- ***For example,*** *at an 18- to 20-degree incline, a conveyor discharge height is approximately one-third of the conveyor length. So, a 27m conveyor at 18 degrees has about a 9m discharge height -*

Through basic Trigonometry and geometry, the volume of a conical-shaped stockpile can be expressed as follows:

$$Volume = \frac{\pi * H^3}{3 * tan^2(\emptyset)}$$

H = Stockpile Height
Ø = Angle of Repose of the Stockpiled Material (~35-degree for RAP)

When building a crushed RAP into a conical stockpile using a **stacking conveyor** (27m conveyor length on an 18-degree inclination), the needed stockpiling area will be roughly 500m2 with a stockpile capacity of 1,075 Tonne of RAP

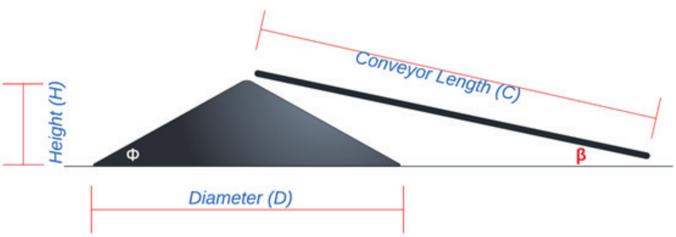

Figure 11 - Calculating the stockpile area based on conveyor belt length, height and angle.

- Using radial stockpiling techniques would increase the stockpiling capacity. A 90-degree radial stockpile contains about four times the material that a conical stockpile of the same height contains. A conical stockpile built with a 50-foot conveyor holds approximately 500 tons, while a 90-degree radial stockpile built with a 50-foot conveyor holds 2,000 tons. SOURCE

Conveyor length (ft)	Capacity (ton) Conical stockpile	Capacity (ton) 90-degree stockpile
50	500	2,000
60	800	3,200
80	2,000	8,000
95	3,000	12,000
110	4,000	16,000
125	6,000	24,000
150	10,000	40,000

Source: Superior Industries, Morris, Minnesota

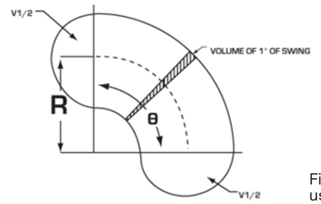

Figure 12 - Stockpile volume when using radial conveyor

- There are many tools that can be used to estimate the maximum tonnes that can be stockpiled using radial or stacking conveyors as a factor of conveyor length and conveyor angle of inclination - SOURCE

Other Stockpiling Considerations

– **Strategically placing the stockpiles between the plant and concerned neighbours presents a sound barrier to keep the noise of daily operations from drifting into new neighbourhoods.**

– **Many producers elect to place their least-used materials furthest from the plant and closest to the edge of their property 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.**

– **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 before 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, 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 courser 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, 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.

Good Roads

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