RAP Source Best Practices

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High variability of the RAP is commonly known as one of the major hindrances for incorporating higher amounts of RAP in the 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 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 is 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. Using crushing or screening plants with discharge conveyor systems presents opportunities for improving safety and increasing the possible stockpile size while reducing the time and cost of stockpiling RAP. However, some considerations 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 assists 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 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 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 stockpile moisture content by half with managing the stockpile's orientation 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 reduce 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.

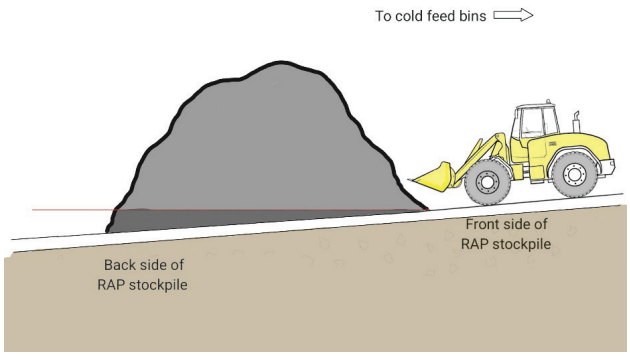


Figure 19- Managing Stockpile Moisture Through Sloping and Paving the Ground Surface

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%
Screen-ing	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 a plastic tarp is not recommended.

• According to J. Don Brock, 2007, the cost of building a 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. SOURCE

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

• Managing RAP source moisture is a crucial 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 possible, and then raised as the stockpile is built.

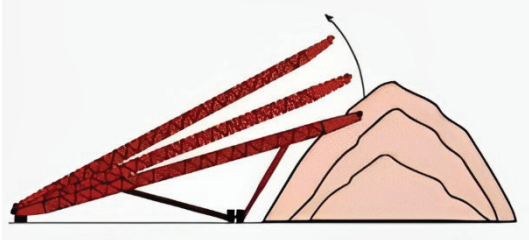


Figure 20- Variable Height Conveyor Best Practice Segregation (Jerry Nohl, 2000)

• Radial stacking conveyors offer improved material distribution compared to traditional conical stockpiles by sweeping left and right to reduce segregation within the pile. However, some segregation of coarse materials may still occur along the outermost edges of the stockpile.

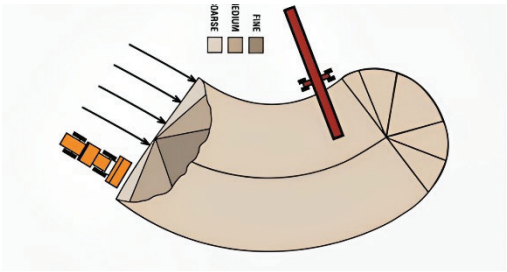
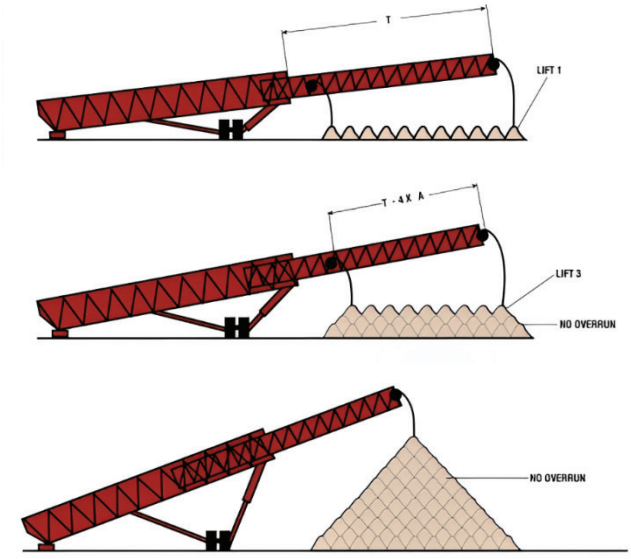


Figure 21- Radial Stacking Conveyor Limits Segregation (Jerry Nohl, 2000)

• 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.



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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.

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 to pass through the screen to bypass the crushing process.
  · When you process large amounts of RAP millings with lot of fines, a mobile screen helps to reduce wear costs and increase total production

- **Increasing Efficiency**
  · It is vital 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 a 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 increase production and lower wear costs.
  · The smaller the infeed or the finished products gets, the more screening capacity will be needed.

Fractionation

· RAP fractionation is the process of separating RAP based on top size to reduce variability and limit crushing effort as well as dust generated from unnecessary 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 lower the variability of the final mix production, especially concerning 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 process should be well controlled to avoid the 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 (P_{200}) 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 the least processing cost and effort.
- **Millings From Multiple Sources**
  · Blending of material during processing operations is key to achieving a consistent stockpile from multiple RAP sources.
  · A bulldozer, excavator, or similar equipment is 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 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 tend to build up on screen equipment, conveyor belts and clogs crushers, leading to additional equipment maintenance.
  · It is important to screen off and remove RAP fines before 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 in order for it to be used as a component in a new asphalt mix. Material variability such as under/overestimating 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 material, 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 three (3) specimens.

Sampling Procedure

- It is recommended that samples be taken as the stockpile is being built to provide a 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.

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