RAP Management Optimization Study

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Abstract

The Saskatchewan Ministry of Highways and Infrastructure (MHI) recently contracted SNC Lavalin to undertake a Reclaimed Asphalt Pavement (RAP) Management and Application Study to identify and optimize areas of use for RAP materials. With depleting aggregate sources across areas of the province, RAP is considered a valuable recycled material with surplus quantities generated from construction and maintenance activities across the province's highway network. RAP materials generated from MHI's construction contracts typically is either:

- Made available to Contractors to reincorporate in new hot mix asphalt concrete with an expectation; but no assurance, that bid prices will be lowered to reflect the value of the RAP; or
- Stockpiled at Ministry locations for future maintenance or construction uses (with fluctuation of inventory levels depending on current demand).

One of the outcomes of the study was the generation of a RAP management plan. The RAP management plan was developed by considering current uses of RAP in Saskatchewan at a consultant, contractor, and Ministry level; best practices in other jurisdictions; and experience with RAP utilization by other agencies. This paper presents the RAP management and re-incorporation processes developed in the form of an optimization table and decision flowcharts for use during the design, construction, and operations phases of the roadway including survey results which served to guide the development.

1 Report Purpose

The Saskatchewan Ministry of Highways and Infrastructure (the Ministry) was seeking recommendations, guidelines, and directives to assist in creating a Reclaimed Asphalt Pavement (RAP) Management Plan for internal use across all its divisions. The driving factor behind this undertaking was to be centred around sustainability, which Engineers Canada describes as *"the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs, through the balanced application of integrated planning and the combination of environmental, social, and economic decision making"* (Canadian Council of Professional Engineers, 2005). A paradigm shift is required in the transportation industry in Saskatchewan when determining the value of RAP, as it is often viewed differently be the various stakeholders. Contractors will typically view and RAP not able to be incorporated into the hotmix as a nuisance material. The Ministry construction managers have an inconsistent knowledge base as to how to best apply the RAP and do not always use it in high value applications. Ministry operations personnel view the RAP as a "free" resource that can be used in different aggregate applications without impacting their material budgets.

The most common definition of RAP is existing asphalt pavement material (such as asphalt concrete or cold asphalt mix) that is reclaimed either by milling or ripping and then removed from the road. It may be milled and of mixed consistency (e.g. produced from a cold planer), larger pieces removed via ripping, or reprocessed which may include crushing or re-pulverizing. For the purposes of the report, materials removed by Full Depth Reclamation (FDR), Cold In-Place Recycling (CIR), and Hot In-Place Recycling (HIR) also considered as RAP.

The Ministry of Highways and Infrastructure Plan for 2019-20 highlighted its strategic goals for the fiscal year. Two goals of the Ministry contained in the plan continue to be: to **improve safety and environmental sustainability** and make a **commitment to excellence**. The RAP Management Study targeted these goals by encompassing the following actions:

- Setting out recommendations to developing a culture in pursuit of providing innovative solutions with RAP construction uses; thereby, reducing the Ministry's impact on natural resources and the environment;
- Engaging with Ministry staff from a wide range of business units for direction of policy and recommendations, and ensuring all employees that encounter RAP are provided with tools and knowledge about acceptable uses;
- Engaging with industry stakeholders to collaborate and determine constraints and opportunities in RAP use;
- Setting out recommendations that promote knowledge sharing of existing information and create lessons learned opportunities on all future RAP use in design, construction, and maintenance; and
- Setting out recommendations for Design Criteria that acknowledge the high value of RAP, improved utilization, reduction of emissions, and lower life cycle cost, during the selection of alternatives.

Saskatchewan has a relatively mature road network comprised of 26,211 kms of highways, which includes 11,593 km of asphalt concrete pavement, 3,909 km of granular pavement, 4,700 km of thin membrane surface (TMS) highways, 5,730 km of gravel highways, and 279 km of ice roads. Rehabilitation projects (repaving projects) will continue to face challenges such as width constraints, increased haul distances for virgin processed aggregates, and ongoing gravel pit depletion. The degree of individual knowledge regarding RAP use, constructability, and performance is substantial in Saskatchewan. Formal administrative tools were developed for the design, management, construction, and maintenance phases to ensure RAP use is being encouraged, usage is being tracked, and performance can be confirmed on a provincial and project by project basis.

Short-term and long-term program goals for optimized RAP utilization cascade down to the project level. Ensuring a high level of RAP usage within each project contract is not common in design decision making and contract specifications. With an increasing desire to optimize the use of resources available, the use of RAP was evaluated throughout all phases of a project: conceptualization, planning, design, and construction. Hand-off to maintenance and their respective activities were also considered (i.e. post project).

The recommendations of the report are currently being evaluated by the Ministry to determine what may be implemented. The findings within this report are based on the existing state of local practice and knowledge within Saskatchewan and can be adjusted as technologies, local knowledge and local conditions change.

2 Current State

Construction practices involving Reclaimed Asphalt Pavement (RAP) use are highly dependant on the contractor's willingness and ability (i.e. mix design constraints) to use RAP in new hot mix asphalt concrete (HMAC) construction and the Ministry's eagerness to specify the use of RAP in standard and non-standard construction practices. Currently, under MHI's 4112 End Product Specifications for Hot Mix Asphalt (EPS), contractors can incorporate up to 20% of RAP measured as a percentage of total binder content. Based on data received from the Ministry, the percentage of RAP incorporated into HMAC has been increasing significantly over the past three (3) years As illustrated in Figure I.

Though RAP incorporation in HMAC is increasing across Ministry projects, the amount of RAP incorporated in each mix design or project has remained relatively constant over the last three (3) years of production As illustrated in TableTable I II. From 2017 to 2019 the percent of RAP, as a portion of the total mix, increased from 3.5% to 7.1% when comparing all HMAC produced in the province. However, within all projects that incorporated RAP into the HMAC, the average percent RAP as a portion of total mix decreased from 12.0% in 2017 to 9.6% in 2019.

A literature search as well as a review of recent technical research indicates that the majority of road authorities are limiting the percentage of RAP added to HMAC to less than 20% without binder modifications. The reason for this recognizes that percentages in excess of 20% negatively impact pavement performance unless there are offsetting measures incorporated. Some jurisdictions have established protocols for the detailed testing of asphalt binder in the RAP materials and then using blending curves to allow greater percentages (the new base asphalt cement being added is adjusted to account for the old, aged asphalt cement from RAP). This does come at an increased cost depending on the availability for virgin processed materials and respective economics.

Many of the roadways within Saskatchewan have incorporated different types of surface treatments and patches over time; therefore, each RAP source has varied material properties and cause difficulty in standardizing its use. This variability also limits the amount of RAP that can be implemented in HMAC while still maintaining the high quality that the Ministry requires. While other jurisdictions have large scale operations that allow contractors and Agencies to stockpile RAP in a centralized location, Saskatchewan places less than 1 million tonnes of HMAC per year across a large, spread out road network. This creates small stockpiles throughout the province and the need for smaller localized gravel sources and mobile crushing and mixing operations. The RAP currently stockpiled in these localized areas is not currently tracked as an asset or valued.

2.1 Current Ministry RAP Uses

Saskatchewan has many challenges efficiently incorporating RAP into various construction projects in the province as shown in Figure III. Fifteen (15) construction surfacing projects undertaken in 2019 were evaluated for RAP. Eleven (11) of the projects produced millings to be used on the construction project. The most common use of RAP in 2019 was as an additive material at the asphalt plant for the production of HMAC. Approximately 38.0% of all RAP produced on the 2019 surfacing projects was being incorporated into the production of HMAC. Approximately 33.1% of RAP produced on surfacing projects in 2019 was stockpiled in Ministry yards and then used for Ministry maintenance activities. Shoulder shimming incorporated RAP to allow for more structural width eliminating the need for granular materials or significantly increasing the surfacing thickness. RAP utilized within the hot mix was split: <= 15% and > 15% of the total aggregate blend for analysis purposes. Figure II displays a breakdown of RAP uses.

RAP Inventory

The current RAP stockpile inventory was tallied with assistance from MHI. An inventory tracking tool (spreadsheet) was developed to assist with data collection. The tool was later enhanced to track other products such as base aggregate, seal aggregate, salt, liquid asphalt. The total number of stockpiles and quantity is summarized in Table III.

The average size of a stockpile was 2,600 t, and the median pile size was 1,220 t. A conversion factor of 1.8 was used to convert m^3 to tonnes.

The inventory tracking tool prompts for data entry to multiple fields including:

- **Tonnage:** Amount stockpiled, used, and currently in the pile;
- **Identification:** Fiscal year stockpiled, Region, business unit, Stockpile site, Pit Identification, Stockpile number, stockpile name;
- **Location:** One of Northing / Easting, latitude and longitude, or legal land description;
- **Description:** Method of volume determination, method of removal, material description, top grain size, variability, remarks and comments, date stockpiled;
- **Usage:** Summation of tonnage removed from stockpile.

Figure IV displays an example of data requested and entered by MHI personnel.

The tool can be modified to include comments and direction for users to ensure required information is captured.

In the future MHI will document the location, quantity, and quality of RAP stockpiles after construction occurs. A number of administrative steps will be implemented to ensure MHI is capturing the required information. It is advantageous to know the engineering properties of the materials in order to compare the performance of RAP to the performance of virgin. Study recommendations wee as follows:

1. RAP should be identified in the same manner as base aggregate and seal coat aggregate. The ministry should assign an internal dollar value to reclaimed asphalt concrete to be applied when maintenance and operations use RAP. Maintenance would still be given the opportunity to request RAP to be stockpiled for later use. As the material is used it would be charged back to the maintenance project; therefore, District managers and staff would be required to track and document the amount used.

2. Update / Revise the Stockpile Addition Form for stockpiled RAP. Construction administrators must submit the information to MHI as specified Schedule A of Consultants' Professional Service Agreements should be changed accordingly.

3. If large volumes of RAP are being stockpiled, samples of the milled material should be tested Specific testing of the stockpiled RAP material would include:

   – Aggregate gradation;
   – Binder content;
   – Grade of aged binder.

4. Begin cataloguing construction uses with additional comments of the project's successes and failures.

5. An inspection / investigation schedule should be developed for each individual project to determine field performance over time. This is essential in determining life cycle project costs, and if RAP is a comparable alternative to virgin aggregate in each specific type of use.

2.1.1 Jurisdictional Review

Various jurisdictional papers on best practices and design with RAP were reviewed. Surveys were also distributed to various jurisdictions around Canada through communication with agencies and TAC boards as well as to Ministry staff, contractors and consultants in Saskatchewan. Each survey contained approximately 25 questions to obtain feedback on how the industry used RAP and to collect information on ways to improve the use of RAP. Responses were the strongest from MHI, as shown in Figure VI.

One of the key study goals was to evaluate the best methodology to encourage increased percentages of RAP incorporated into HMAC. The responses for this question as shown in Figure VI highlights the importance of including all areas in developing new processes in the use of RAP.

All jurisdictions identified surplus RAP as a valuable resource although most stated that they do not gain value in transferring ownership of the excess RAP to the contractor after construction. This typically has led to a majority of jurisdictions retaining ownership of the RAP for future capital work or operational use as shown in Figure VII.

Typical uses of RAP was to limit the RAP % in HMAC to less than 30% in the shoulder and bottom lift and to less than 20% in the top lift. RAP was limited to below 50% in granular layers but was allowed at up to 100% in traffic gravel.

Responses varied significantly as to the method of monitoring the quantity of RAP being incorporated into the HMAC. As shown in Figure VIII the most common methodologies were using the mix design values and having the contractor monitor. The responses also identified other methodologies under development such as binder extraction or having a plant manager within the asphalt plant documenting the RAP belt scale.

A range of responses were received on how to increase the RAP percentage within HMAC. Most jurisdictions either felt that more research was needed or that the maximum already was being done.

2.1.1.1 Ministry Survey Results

The survey was sent to Ministry managers within construction, design and operations.

Ministry specifications currently specify how surplus RAP is to be disposed of. The most common outcome, as identified by Figure IX, is to stockpile if for maintenance uses. The range of maintenance uses within the Ministry is quite broad as shown in Figure X. The most common uses were on approaches, failure repair material and shoulder widening and shimming.

When asked about knowledge on the use of RAP, an overwhelming majority of the managers within the Ministry said they need more training in the use of RAP as is shown in Figure XI.

Ministry personnel had a range of responses when asked how to increase the RAP percentage within HMAC. Most managers either felt that more research was needed in order to understand the impact on HMAC quality or that a bonus structure associated with the percentage of RAP would provide the best incentive for contractors.

2.1.1.2 Contractor Survey Responses

The survey was delivered to the membership of the Saskatchewan Heavy Construction Association (SHCA) in October of 2019. Response was limited, partially due to the late construction season. However, of the 9 responses provided there were a number of answers that provided insight on how the construction industry in Saskatchewan views RAP.

Contractors were asked a number of questions regarding how they value RAP within the bidding process and at the conclusion of the project. The responses were split on whether it affected the bid price as shown in Figure XII, but most contractors were able to sell the excess RAP after the contract.

Each contractor respondent had experience with RAP and had knowledge on what the key elements in a successful project areas shown in Figure 2.15.. The contractors did not feel more research was needed but rather adjustments to specifications including changes to pay adjustments and bonus structures were key in increasing the RAP percentages as shown in Figure XIII.

2.1.1.3 Consultant Survey Responses

Consultants are used by MHI to administer most construction projects and therefore it was important to receive feedback from the consulting industry. The survey was distributed to the members of the Association Consulting Engineers Canada – Saskatchewan (ACEC-SK).

ACEC-SK members identified a wide range of RAP uses as shown in Figure 2.17. The most common identified uses were within the HMA, on approaches, and shoulder widening and shimming similar to the response from the Ministry.

Respondents also noted that monitoring quantities of RAP incorporated into the HMAC was an issue. Responses from ACEC-SK varied significantly regarding the method of documentation. As shown in Figure XIV the most common methodologies were using the mix design values and having the contractor monitor.

ACEC-SK also had a range of responses when asked how to increase the RAP percentage within HMAC. Consultants generally indicated that changes to contract specifications and more research would help increase the RAP percentages as shown in Figure XV. None of the consultants indicated that RAP usage was already maximized.

2.1.2 Summary and Recommendations

2.1.2.1 Design Recommendations

- Evaluate grouping hot-in-place projects together to provide enough volume for a sustainable industry.
- Modify surfacing design manual to ensure that in place recycling is evaluated with each project.
- Develop contract specifications for Hot In Place Recycling (HIR), Full Depth Reconstruction (FDR) and Cold In Place Recycling (CIR).
- Formally add High RAP (30%-50%) shoulder paving evaluation to the design manual and develop specifications.
- Increased RAP (15% to 30%) incorporation in HMAC can be introduced with by considering PG graded binder.
- Strive to use RAP in HMAC. If RAP is used as a granular base, it should be blended at least 50% with virgin aggregate to reduce the risk of consolidation.
- Tie RAP content within surfacing HMAC to financial incentives for the contractor.
- Formalize consultation with local communities to determine if using RAP on the local roadways is desired.
- Only include RAP shims if they are being used below a surfacing structure and are placed on top of an existing granular layer.
- Create a standard testing procedure for RAP during its production.
- Use optimization tools

2.1.2.2 Construction Recommendations

- Determine a consistent methodology for monitoring the RAP content being introduced into the HMAC.
- RAP is a suitable aggregate for sub-base. If used as a sub-base, the RAP should be blended at least 50% with virgin aggregate to reduce the risk of consolidation. The use of RAP in these applications should be only done to limit hauling and production of small amounts of aggregates in a contract.
- RAP is suitable as a surfacing aggregate on approach roadways and is a good use of materials to limit haul and match new gradelines.
- The mill speed should be controlled and kept uniform to promote consistency. The mill speed should be checked regularly by the asphalt inspector. The process of crushing and milling RAP tends to increase the percentage of fine particles within the recycled material. The variability of RAP can be reduced with consistent operations (Edil, Tinjum, & Benson, 2012).
- A quality management plan should be implemented for sampling and testing of RAP. If not required by contract documents, contractors should be encouraged to include RAP quality control measures in quality management plans submitted at the time of tendering.

2.1.2.3 Maintenance Recommendations

- Perform a trial mix design process on a number of RAP stockpiles to determine the average percentage of restorative additive required to produce a rejuvenated RAP asphalt mix. Approach suppliers of additives to perform the trial mix design with their additives.
- Perform field trials of 100% RAP surface placement and monitor performance.
- Hold a lessons-learned session with maintenance staff on the completed Ministry maintenance uses of RAP including its processing and placement in different applications.

3 Proposed Tools

3.1 RAP Optimization Table

A RAP Optimization Table was developed in consultation with key Ministry staff by evaluating all the current and known potential uses of RAP and gauging them against a set of criteria. The criteria were categorized: cost effectiveness, technical feasibility, use of natural resources, performance, and haul distance/ emissions. Scoring for each of the five categories were determined by committee during the meeting based on the priorities of the Ministry and consensus discussion.

The first step in the development of the table was to determine all the types of uses of RAP available within the Ministry as well as those recommended to be added in the future from other jurisdictions. The first draft was presented to the Ministry focus group on November 13, 2019 for review. A review meeting (via teleconference) was held on November 15, 2019 where the categories were refined, and the weighting of each category was set as shown in Table IV. On November 18, 2019, the refined category scoring was sent to the focus group for input on each RAP use. After all responses were gathered, the weighted score for each use and category was input into the table as identified in with the scoring criteria identified in Table V. Table VI provides description of each category to assist in determining scores for each use. Results

Project data was collected from Ministry Project Managers for 2019 surfacing projects. Each project was evaluating using the metrics as identified in Table VI. Table VII shows RAP optimization scores of the projects that were scored and ranged from 38.6 to 78.1. The average of the 9 complete projects evaluated was 56.6. This value represents the 2019 construction season and will serve as a baseline to compare future years. Each score is generated by multiplying the weighted score by the percentage of RAP used on the construction contract. A score for Contract No. H18036 was not included because all the RAP uses were unknown at the time of submission. A summary of scores by RAP use is shown in Table VIII.

The following formula is used to develop the score for each project.

$$\sum RAP\ Weighted\ Score\ x\ \frac{tonnes\ used\ per\ construction\ use}{total\ tonnes\ of\ RAP\ generated}$$

The three highest scoring projects have the highest percentage of RAP incorporated into new HMAC.

3.1.1 How the RAP Optimization Table Is Used

The first step for the designer is to input the cost estimates and average haul distances for various products to be used on the project. Once complete, the designer will review each surfacing option chosen and determine the amount of RAP generated on the project. Once known, the designer will follow the RAP design flow chart to further evaluate the major construction choices available for the RAP. After the major choices are completed, minor applications can be specified within the design for the remainder of the RAP. For each application chosen, the quantity of RAP used will be entered into the optimization table. Follow the design flowchart to allocate the RAP usage to the optimal uses. Once all the RAP is accounted for the total ranked score for the design option is shown for the design report.

During construction, the construction administrator is tasked to monitor compliance to the contract requirements. If the designated application is not practical due to changed conditions, the construction administrator shall identify the applications chosen for the RAP and inform the Ministry by creating a draft Supplemental Agreement (contract change) for consideration. The optimization table should be updated with actual amounts of RAP used during construction.

3.2 Design Flowchart

A significant limitation in the optimized use of RAP is determining its uses too late in the delivery of a project. Therefore, the design phase of the project should identify whether RAP will be produced and what end uses are best for the RAP in order to optimize the use of RAP. This is a departure from standard paving contracts where the Contractor assumes ownership of surplus RAP and disposes it as they so choose. SNC-Lavalin developed a decision matrix to be used in conjunction with the optimization table in order to prioritize the use of RAP within a project and other Ministry activities.

The Design Flowchart was developed as a prioritization system allowing the designer to flow from high priority uses to the lower value uses and therefore lower priority uses in a standardized method. The order of questions is as follows:

- **Is the Existing HMAC surface <100mm thick?**
- **Is the design choice an in-place recycling design?**
- **Is there RAP produced in the design choice or are there RAP stockpiles available from previous projects?**
- **Is the RAP available consistent in gradation and free from patching and seal coats?**
- **Are there millings remaining?**
- **Are the shoulders ≥ 3.0m in width and the project > 30,000 tonnes of HMAC surfacing?**

3.3 Construction Flowchart

The flowchart for construction follows the same theme as the design flowchart. The decisions made will help to prioritize the use of RAP within the higher value uses and further optimize the choices.

- **Is the construction method an in-place recycling project?**
- **Is there RAP produced or are there RAP stockpiles from a previous project identified in the contract?**
- **Is there RAP remaining outside of design allocations due to construction changes?**
- **Are there additional construction uses for the RAP as an aggregate within the contract?**
- **Is the Ministry maintenance team willing to take more RAP in stockpile?**
- **Are local communities wishing to purchase the RAP for stockpiles?**

3.4 Operations Flowchart

Maintenance operations for existing stockpiles would be dependent on the needs of the local maintenance team. The types of potential uses as well as the requirements of each use could be identified by the maintenance supervisors in a lessons learned session. In general, the flowchart for operations would go from high value use of TMS enhancement to the lowest value use of embankment fill.

1. TMS Enhancement
2. Service Road Surfacing
3. Approach Road Surfacing
4. Shoulder Shimming

5. Base Replacement
6. Failure Repair
7. Subbase Replacement
8. Dust Control
9. General Maintenance Aggregate
10. Embankment Fill

4 Optimization Prioritization Recommendations

The Ministry is working on many different directives in order to utilize the RAP within construction projects and by maintenance after construction. This progress can be further strengthened by utilizing 5 key recommendations within the Ministry.

1. **Develop specifications for RAP uses to use within special provisions.** This recommendation would allow for a consistent message to contractors and provide Ministry staff and representatives of the Ministry to administrate each contract consistently. As new or uncommon RAP use procedures are completed each year the specifications can be refined with lessons learned.

2. **Change methodology for stockpiling RAP to include monitoring, documentation and fractionation**. Current RAP stockpiles in Ministry yards are not typically separated by sources or quality of RAP. By monitoring the quality on Ministry property there are opportunities to include the RAP within future projects at a higher value than as a simple aggregate replacement.

3. **Link RAP % within HMAC to pay adjustments.** Having RAP % tied in to pay adjustments was recommended consistently within feedback from jurisdictions, consultants and contractors. Increasing the RAP % within the HMAC above 15% requires more effort from the contractor in quality control and mix design. Without a financial incentive the contractor will not take on the extra cost and risk of adding more RAP.

4. **Change design process to require 100% RAP allocation within the design report.** Current design processes show some evaluation of in place recycling as an option but since this process is not well known in Saskatchewan, typical designs do not recommend this as a design choice. Common practice is to only start to look at RAP uses during the tender document phase. If the priority is set during the design phase that 100% of RAP produced needs to be allocated more conversations with maintenance and local communities would be required during the design phase.

5. **Lessons learned training session within Ministry to share the existing RAP use knowledge.** Many regions within the Ministry have long standing high utilization of RAP while others have no experience with RAP in higher value uses. Regular discussion and lessons learned presentations between various Supervisors of Operations, District Operation Managers and project managers on RAP uses would spread the knowledge around as to the benefits and drawbacks of each use. Further, the sessions would ensure the knowledge was not lost as the experienced staff retire.

5 References

Canadian Council of Professional Engineers. (2005). *National Guidelines on Environment and Sustainability*. Retrieved from http://www.enggeomb.ca/pdf/Guidelines/ccpe-esd-guide-nov2005.pdf

Edil, T., Tinjum, J., & Benson, C. (2012). *Recycled Unbound Materials.* Minnesota Department of Transportation.

6 Figures

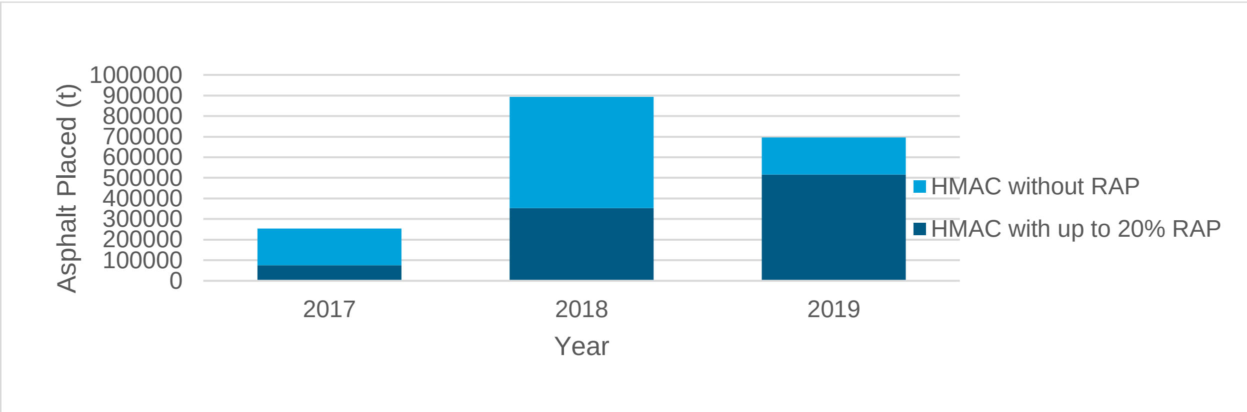

Figure I - HMAC Placed with RAP Incorporation

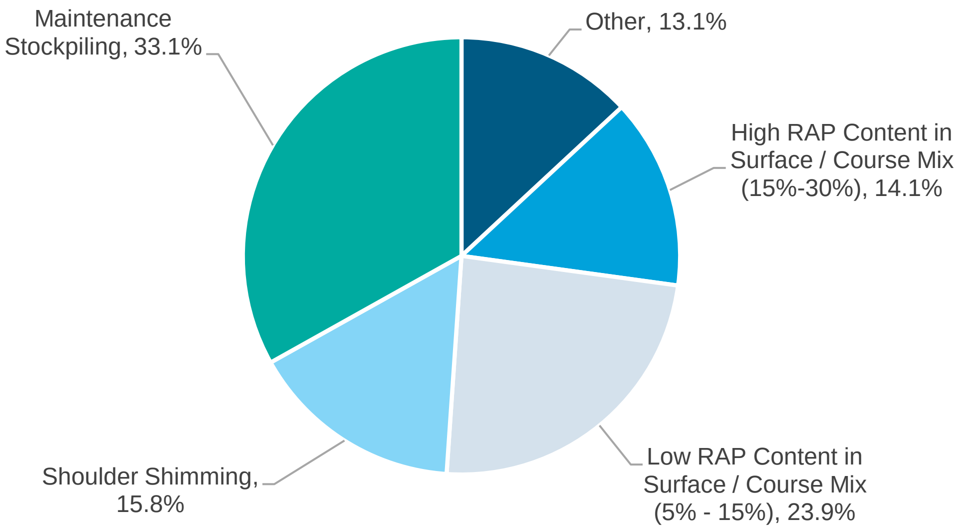

Figure II – RAP Uses in 2019

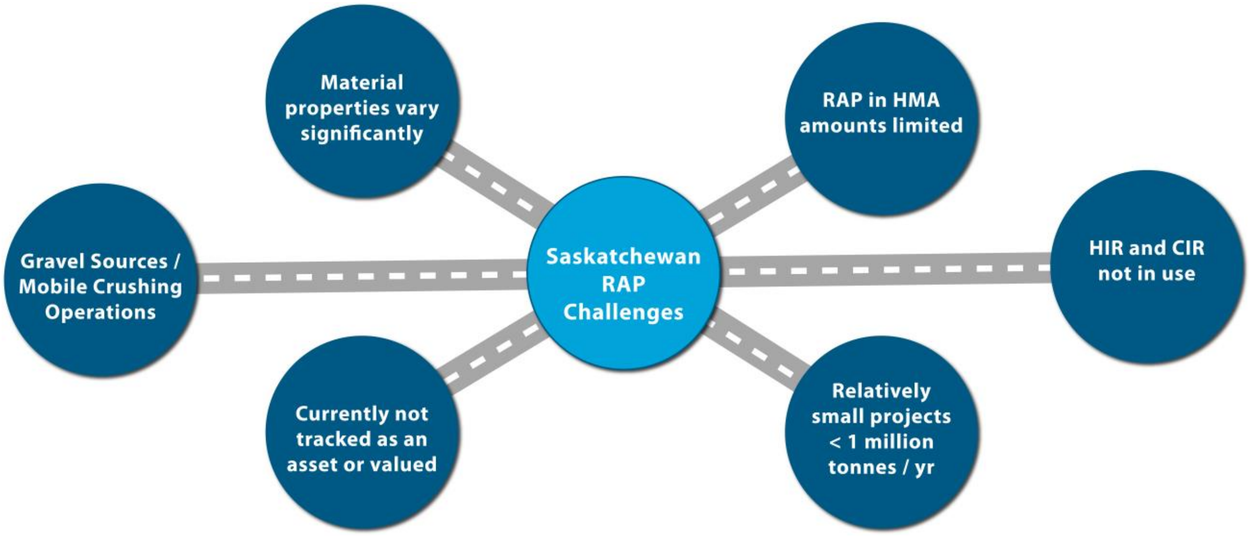

Figure III - Saskatchewan RAP Challenges

Tonnage			Identification							
Stockpile	Used	Remaining	Yr	Region	Business Unit	Site Description	Stockpile Site	Material Code	Pit Identification	Stockpile Number	Stockpile Name
1550	-200	1350	2019	Central	8104	MELVILLE	6103	35	62L-101	62L-101-01	Reinson Stockpile

Location					Description						
Northing	Easting	Latitude	Longitude	Land Location	Method of Volume determination	Milled / Re-processed / Unprocessed	Material Description 1	Material Description 2	Estiamted Top Size	Removed from	YR stockpiled
	-	-	-	NW11-23-07-W2	RTK Survey	MD	Clean, no waste, minimal earth in stockpile		3/4 "	47-07	2018

Description					
Remark	Consistant - Variablity	Other Comments	Date Entered	Entered By	Active Stockpile
50 mm millings from KM 23- KM 19 - Wirtgen 2100DCR	Appears Consistant - no large chunks present	NA	10-Sep-19	T.Inglis - SNC Lavalin	Yes

Usage								
R1 (t)	R2 (t)	R3 (t)	R4 (t)	Sum of Removed	Date Removed	Purpose	Locartion of Use	Comments
-200				17-Oct-19	Deep Patch Material	KM 15 47-07 LT SHLD	Chunks larger than 4" had to be waste, under 5 % wasted	Slight rutting present in outer wheel path after 2 weeks

Figure IV - Snapshot of the Inventory Tracking Tool for RAP Stockpiles

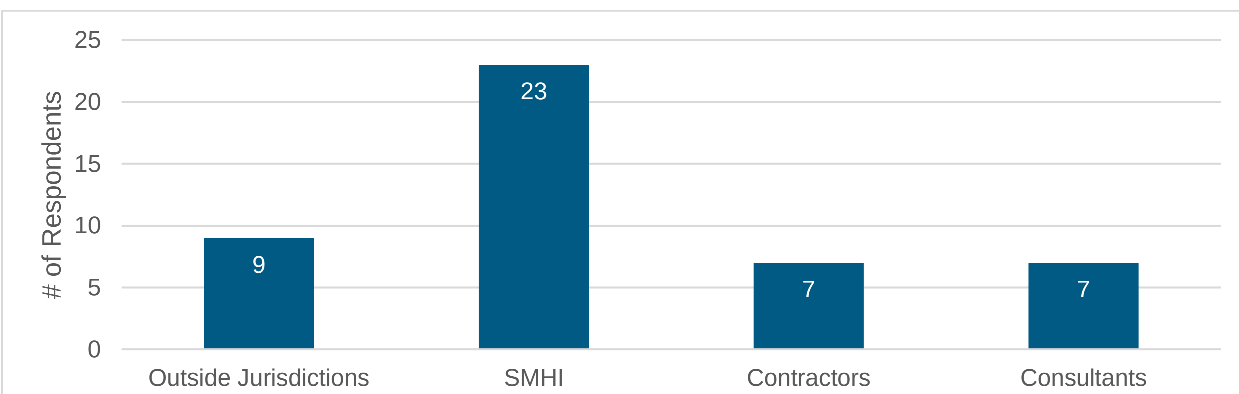

Figure V Survey Responses by Sector

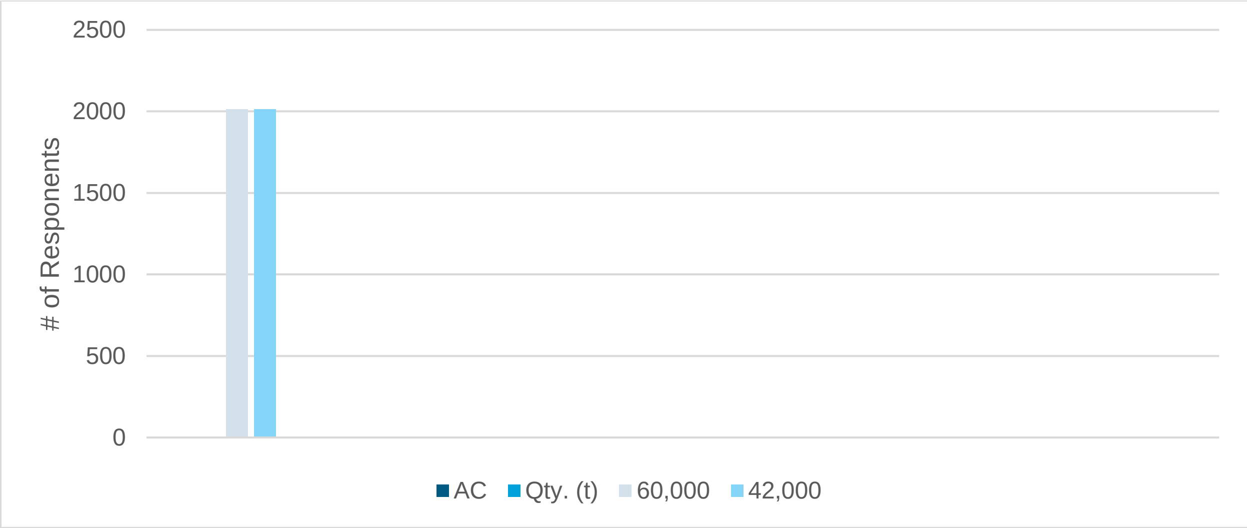

Figure VI Methods to Incorporate Increase RAP in HMAC by Sector

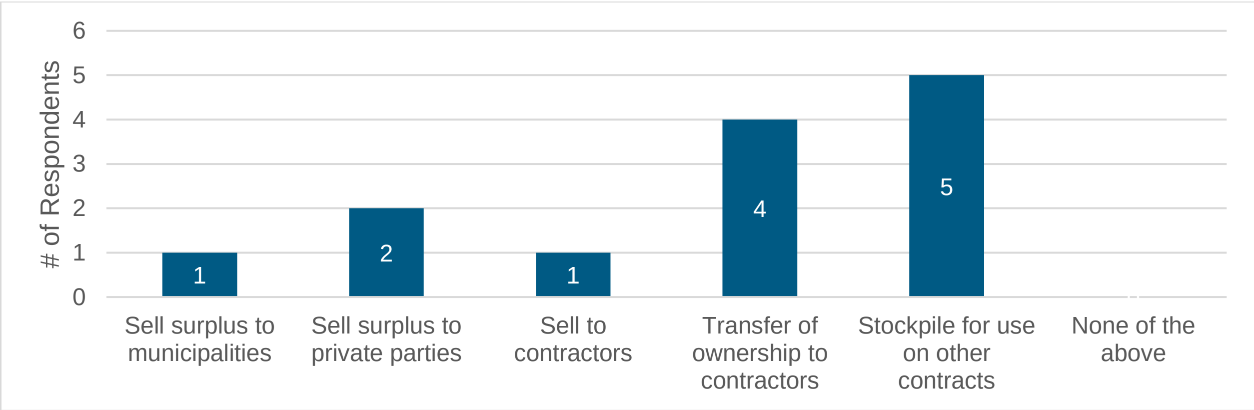

Figure VII Destination of Excess RAP After Contract - Jurisdictions

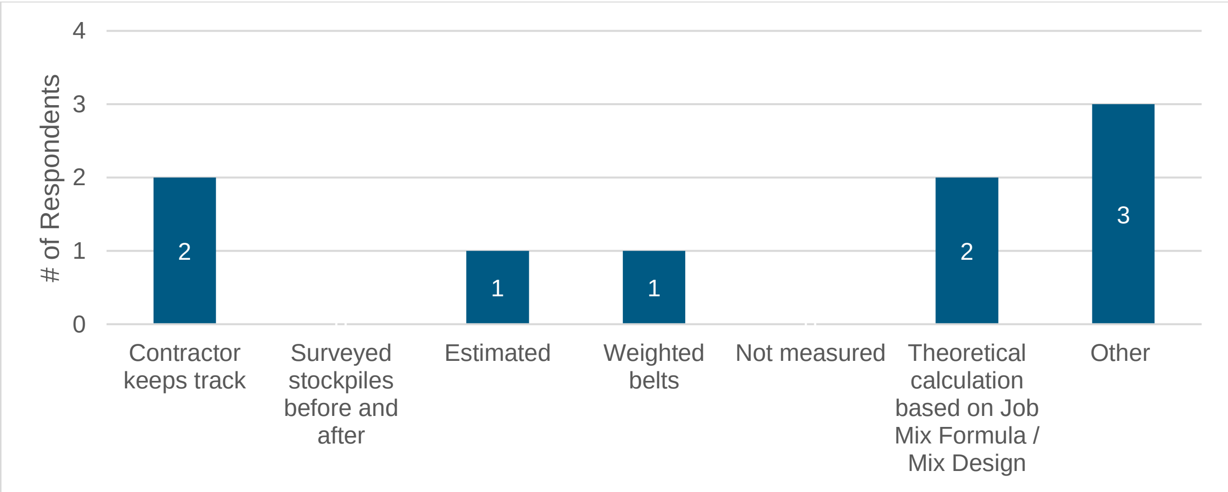

Figure VIII Method of Documenting RAP % in HMAC - Jurisdictions

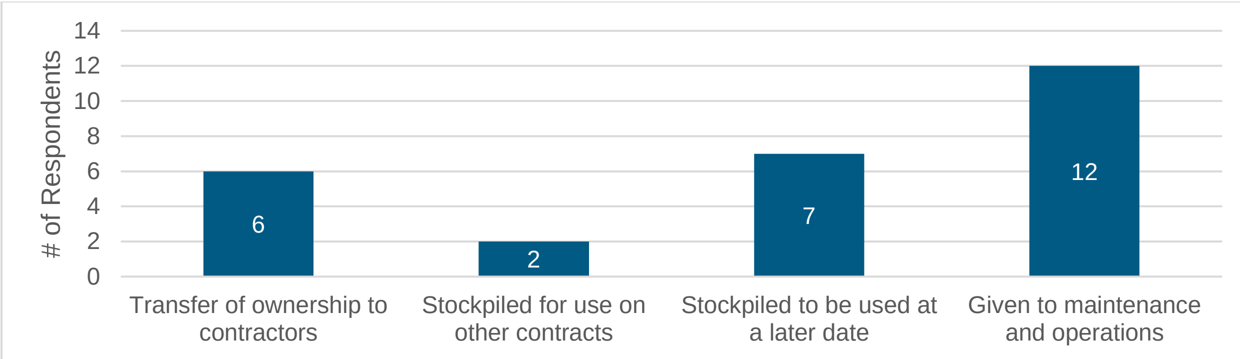

Figure IX Destination of Excess RAP After Contract - Ministry

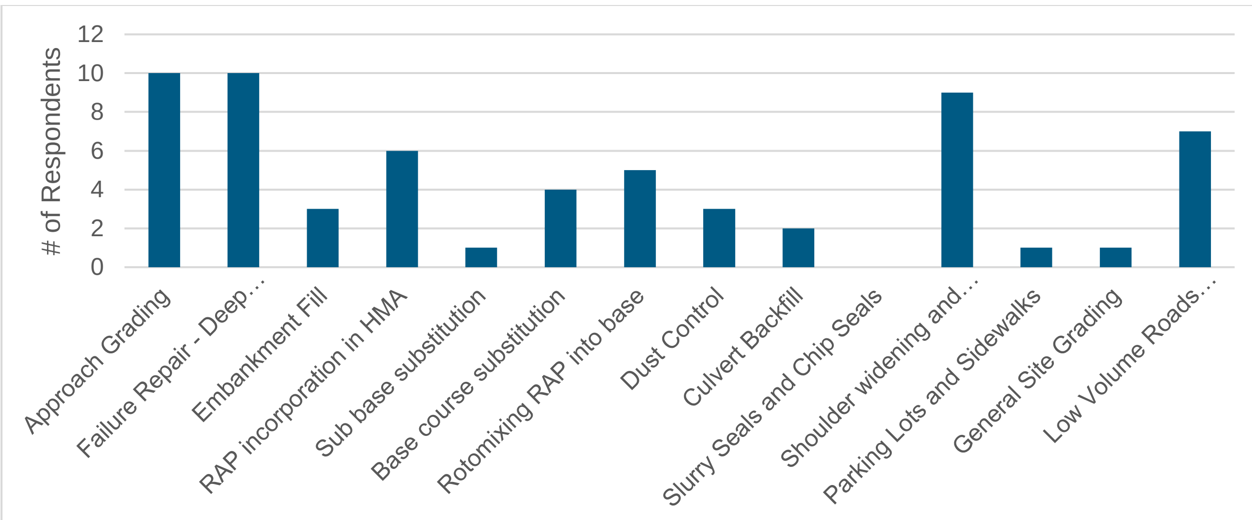

Figure X Current RAP Uses - Ministry

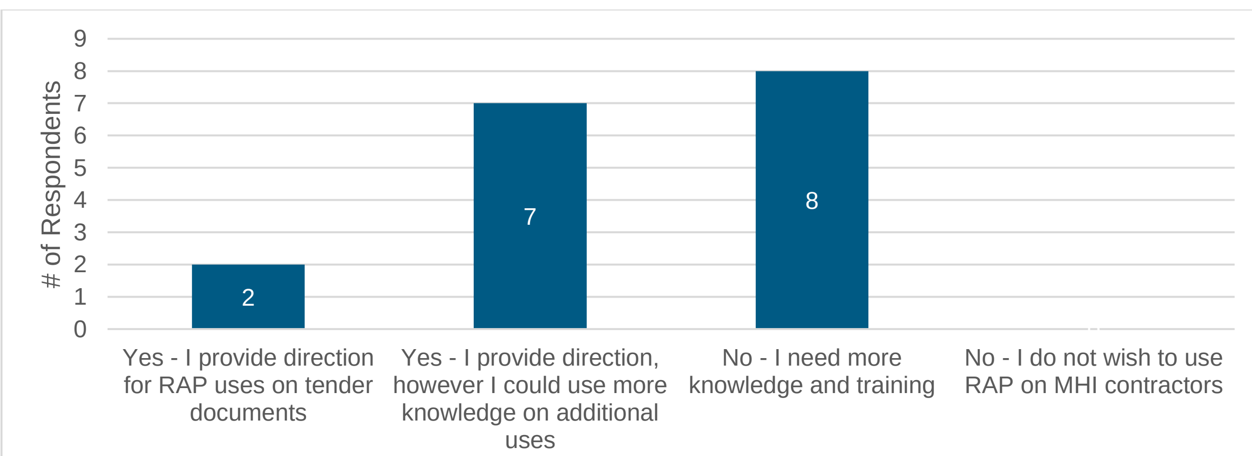

Figure XI RAP Use Level of Knowledge - Ministry

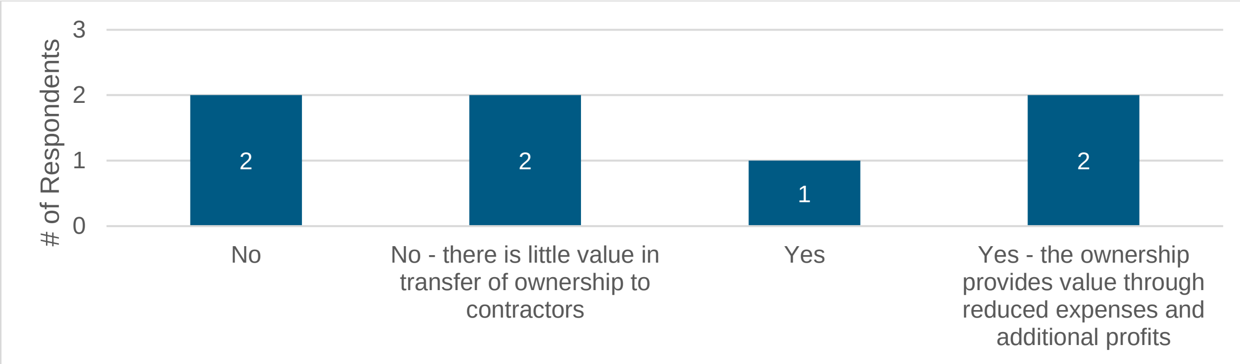

Figure XII RAP Ownership Effect on Bid Price - Contractors

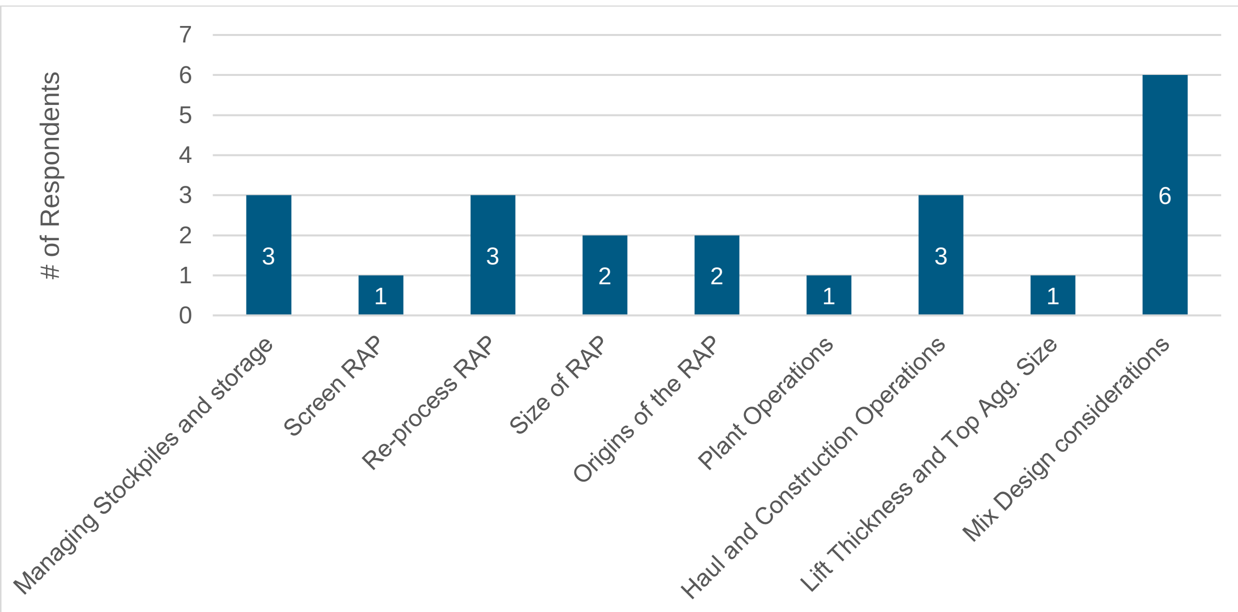

Figure XIII Key Components to Using RAP in HMAC - Contractors

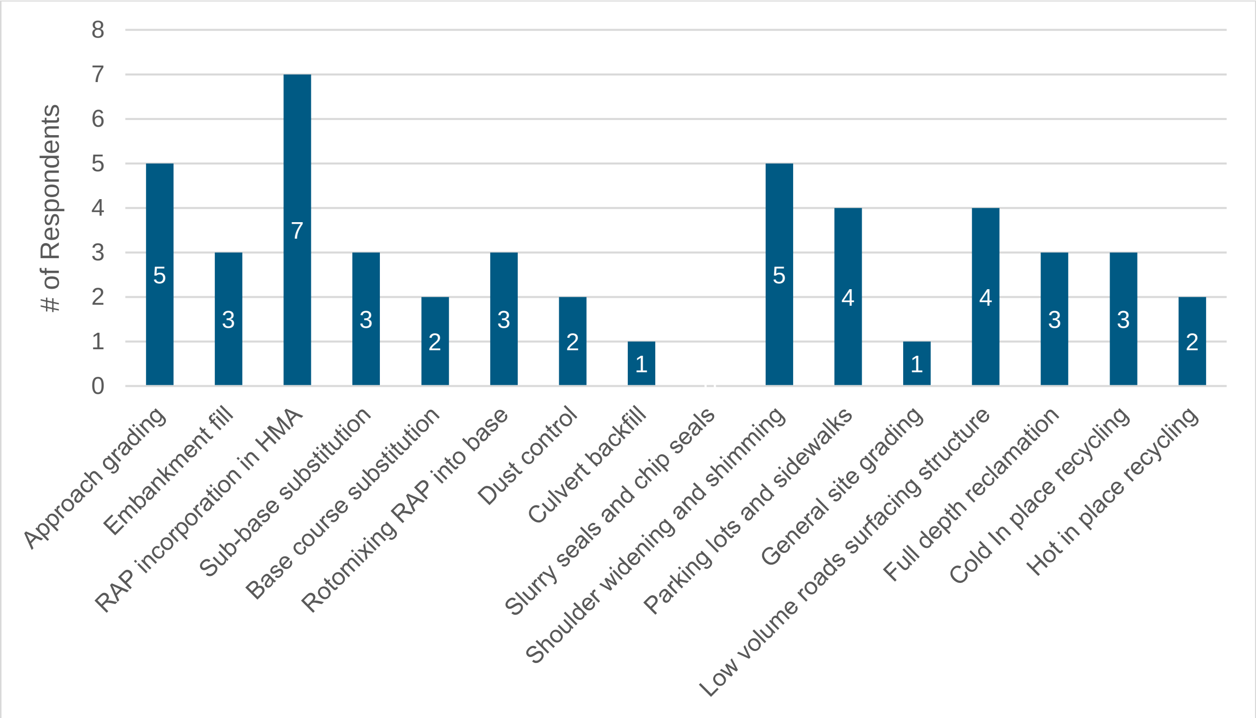

Figure XIV Current RAP Uses – ACEC-SK

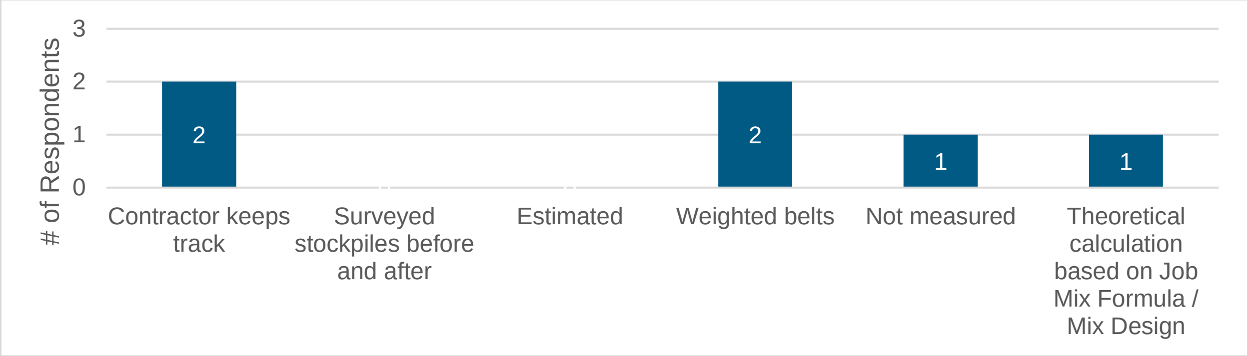

Figure XV Method of Documenting RAP % in HMAC - Consultants

7 Tables

TableTable I II - Percentage of RAP Incorporated into HMAC

Year	Percent of RAP in All HMAC Produced	Average Percent of RAP in HMAC with RAP Incorporation
2017	3.5%	12.0%
2018	4.5%	11.5%
2019	7.1%	9.6%

Table III Total Reported Stockpile Quantity

Region	# of Stockpiles Reported	Quantity (t)
Southern	35	141,240
Central	40	43,030
Northern	5	12,271
Total	**80**	**196,541**

Table IV Category Scoring

Category	Category Weighting
Cost Effectiveness	30%
Technical Feasibility	15%
Natural Resource Feasibility	5%
Performance Feasibility	40%
Haul and Emission Feasibility	10%
Total	**100%**

Table V - Ranking Table Recommended Scores

RAP Uses	Description		
	Technical Feasibility	Natural Resource Feasibility	Performance Feasibility
Hot in Place Recycling	20	100	75
Cold in Place Recycling	25	90	85
Full Depth Reclamation	20	100	90
High RAP Content in Shoulder Mix (30%-50%)	70	85	70
High RAP Content in Surface / Course Mix (15%-30%)	60	80	80
Low RAP Content in Surface / Course Mix (<15%)	100	75	90
Shoulder Shimming	90	75	80
Approach Surfacing	90	70	95
Failure Repair	80	70	65
Base Replacement	80	70	60
Subbase Replacement	80	55	50
Embankment	80	50	40
Service Road Surfacing	100	60	90
TMS Enhancement	100	80	80
Surfacing Community Roads	80	80	90
Dust Control	80	70	80
General Yard / Parking Surfacing	80	50	50
General Maintenance Aggregate Replacement	80	70	45
Given to the Contractor	80	50	0

Table VI RAP Evaluation Tool Scoring Table

Score	Cost	Technical Feasibility	Environmentally Sound	Performance	Location
80 – 100	80% - 100% Cost Savings	Can be implemented without any change to process or equipment.	Significant betterment to environment - e.g. new borrow area would not need to be stripped destroying natural plant an animal habitat.	Performs as good or better than conventional alternative.	Requires hauling of <5km
60 – 80	60% - 80% Cost Savings	Can be implemented with minor change to process with same equipment.	Some betterment - stockpile is used up and area can be reclaimed to natural state.	Slight risk of reduced performance compared to conventional alternative.	Requires hauling of 5 to 25 km
40 – 60	40% - 60% Cost Savings	Can be implemented with minor change to equipment and or process.	No differential environmental impact.	Moderate risk of reduced performance compared to conventional alternative.	Requires hauling of 25 to 50 km
20 – 40	20% - 40% Cost Savings	Requires major change to either process or equipment.	Minor adverse impact - has potential for harming the environment (eg using more aggregate resources than conventional would require).	Significant risk of reduced performance compared to conventional alternative.	Requires hauling of 50 to 100km
0 - 20	0% - 20% Cost Savings	Requires major changes to equipment and process and is not readily available.	Significant betterment to environment - e.g. new borrow area would not need to be stripped destroying natural plant an animal habitat.	Not suitable / simply gets rid of the material.	Requires hauling of >100 km

Table VII - Summary of 2019 RAP Optimization Scores (Post Construction)

Contract No	Year	Control Section	RAP % in HMAC	Project Score
H17084	2019	10-03, 16-13		47.9
H18028	2019	1-19/1-20, 1-21, 1-22A, 21-04	6%	55.8
H18036	2019	16-27B/16-28B	5%	INC
H18046	2019	10-05,1-05A,310-01	12%	68.0
H18050	2019	CS.2-07		38.6
H18073	2019	7-02A&B	12%	73.3
H18082	2019	7-04, 7-04A, 7-05, 4-08, 4-09	17%	78.1
H18095	2019	5-04,5-05,35-11 & 35-12		38.6
H18106	2019	16-16	9%	52.6
H19029	2019	6-13/3-06	9%	56.9
			2019 Average	**56.6**

Table VIII - 2019 Contract Scores by RAP Use

RAP Use	Contract Number									
	H19029	H18106	H18095	H18082	H18073	H18050	H18046	H18036	H18028	H17084
Hot in Place Recycling										
Cold in Place Recycling										
Full Depth Reclamation										
High RAP Shoulder (30%-50%)										
High RAP Content (15%-30%)				**74.02**						
Low RAP Content (5% - 15%)	29.02	19.39			53.51		45.49	90.75	28.36	
Approach Surfacing	**3.63**	3.18							1.46	12.62
Failure Repair										
Base Replacement				**3.79**						
Subbase Replacement		11.36								
Embankment		7.54								
Service Road Surfacing							8.18		0.54	9.37
TMS Enhancement										
Surfacing Community Roads					8.02					
Dust Control										
General Yard / Parking Surfacing										
Maintenance Stockpile	24.23	11.11	38.59		11.73	38.59	14.35		25.39	25.95
Given to the Contractor				0.28						
Ranked Scores	**56.88**	**52.58**	**38.59**	**78.09**	**73.27**	**38.59**	**68.01**	**INC**	**55.76**	**47.94**