INCREASING RECYCED MATERIAL USE

Exploring the Economic Benefits of using more Recycled Concrete Aggregate and Recycled Asphalt Pavement in Construction and Rehabilitation Projects in Metro Vancouver

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Report prepared at the request of **Metro Vancouver** in partial fulfillment of **UBC GEOG 419: Research in Environmental Geography**, for Dr. David Brownstein

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Table of Contents

Executive Summary

One of Metro Vancouver's goals is to increase the amount of recycled materials used in their construction and rehabilitation projects while being economically sustainable, preferably cost saving. The aim is to divert more recyclable materials from landfills, and to reduce stockpiles in recycling facilities. This research paper aims to explore examples from around the world that can be adopted by Metro Vancouver for two recyclable materials in particular: Recycled Asphalt Pavement (RAP) and Recycled Concrete Aggregate (RCA).

This report looks at the current trends in recycling materials within Metro Vancouver acknowledging the barriers associated to their use in regards to a previous undergraduate assessment done on the topic (Ammerlaan). Further into the paper there is more detail on RAP and RCA which explores their uses and success stories in different parts of the world. Once an understanding of the materials has been established, some recommendations are put forward to Metro Vancouver for consideration. Below is a brief summary of the recommendations.

Recommendations	**Brief Description**
Minimum percentages in purchasing agreements	Follow an approach similar to the Hamburg, Germany example, to stimulate innovation, and quality for road rehabilitation and construction using a high amount of RAP as well as RCA as part of the purchasing requirements. Much like fly ash in concrete.
Municipalities could co-purchase recycled material for road construction	Metro Vancouver member municipalities could collaborate to co-purchased or co-process recycled material for road construction. By providing material to processors or processing their own material, municipalities could have better information about the source of the recycled material.
Adopting clear process for piloting and documenting recycled material road construction.	Several contractors in the region use or have tried using recycled material in road construction projects. Creating a clear process for how industry can pilot recycled materials and determining in advance what kind of technical information needs to be documented to encourage more widespread adoption would help provide better information on the performance of recycled material.
Industry could adopt circular economy practices	Constructors could look at using Hot Mix in Place paving techniques to repair the road in situ. Material providers could look at options for leasing material to municipalities opposed to selling it. The idea being to create contracts which would require the material to be returned to the material provider at its end-of-use so that it can then be used in another construction project.
Provincial policy change	British Columbia could adopt a policy that mandates the use of recycled materials in projects.
Supporting innovation	There are companies whose purpose is to create environmentally friendly and cost effective technologies for construction projects by using recycled materials. Partnering with them or having certain agreements where they are funded and therefore furthering their research and development could create new innovative technologies for the municipalities use.
Preparing stockpiled materials to make them more market friendly.	Specific to RAP, blacktop cookies (prepared pothole fixtures) should be pre-made in preparation for fixing and similar market-friendly approaches should be developed for RCA.

This research paper is limited to purely extensive literary review and does not have any primary sources from interviews. To further strengthen the ideas and methods in this paper, Metro Vancouver and member municipality representatives that are involved in the topic and members if industry that are part of the system should be interviewed to gather detailed and more in-depth knowledge on the topic.

Introduction

The demand for recycled materials in Metro Vancouver is increasing as new innovative ideas sprout up to incorporate recycled materials in construction projects. At times, demand is inadequate resulting in several recycling plants being unable to accept all the waste in periods of high volume (Kane Consulting). There is still resistance in many instances to use recycled materials because of several barriers including perceived, regulatory, market, and technical (Ammerlaan). This research hopes to find economically viable methods of increasing the use of recycled materials through a variety of methods such as increasing demand, bettering the image of recycled materials and changing industry standards to facilitate the use of recycled materials. There are several different recyclable materials such as wood, plastic and metal, that due to research time constraints will not be covered in this paper. The focus will be on Recycled Concrete Aggregate (RCA) and Recycled Asphalt Pavement (RAP).

The breakdown of this research paper is as follows, at first this paper will introduce RAP and RCA and give a background on the two with some information about the materials, for example some of their uses. Then it will go on to the method describing how and where information regarding the research was found. The paper will then go into depth on different strategies that exist around the world that are incorporated in the chain of use for RCA and RAP that may be valuable if adopted by Metro Vancouver. Such strategies can save money, better the environment, and reduce or eliminate the amount of material going to landfills, and even to recycling facilities especially if on-site recycling is done using a circular economy model. An example of one of those strategies is the use of “blacktop cookies” for repairing potholes.

Once the different strategies have been explored the paper will then offer recommendations for the increased use of recycled RCA and RAP that are economically feasible, save the municipalities money and divert more recycled materials from landfills and stockpiles in recycling facilities.

Research

According to the Metro Vancouver latest annual solid waste and recycling report (Metro Vancouver), approximately 160,000 tonnes of asphalt and 480,000 tonnes of concrete were recycled in 2013. Based on the latest Metro Vancouver demolition and construction waste composition study approximately 29,500 tonnes of concrete and 48,700 tonnes of asphalt are disposed of each year for diversion rates of 94% and 77% respectively. The concrete and asphalt is sent to a number of small recycling plants that crush the material to create recycled aggregate.

In 2012, Kane Consulting reported that the BC Ministry of Transportation does not purchase any recycled aggregate from local recyclers, but prefers to purchase virgin aggregate for their highway construction and renovation. However, the road construction industry is starting to move towards the use of more recycled material. The 2013 Transportation Association of Canada (TAC) Best Practices Guide for the Use of Recycled Materials in Transportation Infrastructure recommends that 30% RAP be allowed in the binder course mix in highways (MacKay and Duclos). As of December 2012 Section 505 of the Ministry of Transportation Standard Specifications for Highway Construction now allows 15% RAP in the surface course of freeways and primary highways; hopefully, this will start the increased demand for RAP as other road owners in BC adopt similar practices. The TAC Best Practices Guide also states that in British Columbia the secondary roads allow 30% RAP in surface course and 100% RAP in binder course mix.

Road construction is a major market that could absorb more RCA and RAP materials. While a portion of the material is now being recycled, local recycling plants sometimes struggle maintaining a balance of supply and demand. Owners want to save money on disposal fees by sending road construction for

recycling, but many have not yet updated their specifications to allow for use of the recycled materials in their roadways. Subsequently, recyclers are sometimes stuck with large stockpiles of material without a market (Storry).

Another barrier to the recycling of asphalt pavement is current demolition practices. Site and traffic flow constraints often result in the contractor removing the asphalt and road base together. Once combined, the original road base and asphalt slab portions are not economical to separate. Recyclers then end up with a mix of asphalt and road base. While there are good markets for pure RCA and RAP, there are very few options for a mix. The Master Municipal Construction Documents Association (MMCD) is currently reviewing their specifications to determine how best to deal with mixed materials. Also, the BC Ministry of Transportation is currently piloting an asphalt blend fill material. The results of the pilot are expected to be available by the end of 2015.

The majority of RCA and RAP is used in smaller construction jobs for secondary roads as long as the City Engineer approves the materials (City of Vancouver). Unlike places such as Edmonton where recycled fill is mandated for the entire city, the lower mainland has access to virgin material from local quarries. Subsequently, the cost of virgin material in the Metro Vancouver region is marginally more expensive than recycled materials. Small price differentials in conjunction with the perception that virgin aggregate is better than recycled causes challenges to increasing the use of RAP and RCA in road construction and rehabilitation. Changes have been made over the years to satisfy those that want recycled materials to be used more for environmental and economic reasons however, as stated previously, a large quantity of materials are still being diverted to landfills because of a low demand. Other locations such as farmlands in Delta (Ammerlaan) can be seen as making positive use of these recycled materials for construction on farmland dykes, road base, and fill; but they do not always properly manage the contaminants in the materials used on their site that may affect the crops in a negative way resulting in unforeseen remediation costs.

Recycled materials used in new construction projects or even rehabilitation projects has already proven to be cheaper in other parts of Canada. As per Figure 1, using recycled material compared to conventional materials reduce cost by over 40%.

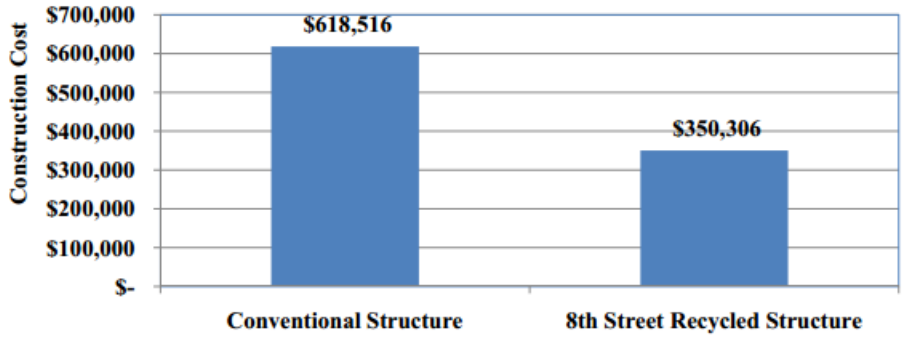

Figure 1 Shown here is the decreased cost using recycled materials (RAP and RCA) for a rehabilitation project for a road in Saskatoon compared to the conventional method of using fresh materials (Foth, Haichert and Guenther).

Method

The paper is informed through intensive literary review used to gather a baseline of information regarding RCA and RAP as well as more in depth technical information on the two materials (various properties of the materials when used in construction).

The literature consulted varied from journal articles to government best guide practices to consulting reports. The government publications provided significant information about how the British Columbia Ministry of Transportation (BC MoT) is involved with RCA and RAP. These sources discussed BC's stance on the limitations, barriers, government involvement, and other aspects of the recycled materials. For example, the best practices guides discussed methods such as hot in-place recycling[1] for integrating recycled materials in a road construction project. The various journal articles looked at specific innovations in the industry, such as the effects of recycled material in new virgin material mixes. These journal articles provided more technical information on how recycled materials change the structure of a finished creation.

One example described the use of RCA in "green concrete" where, depending on the percentage of RCA used, the "green concrete" can range from being minimally less durable to as or more durable than conventional concrete (Alam, et al). These added recycled materials do go through the proper processes to be as clean as possible, screening and washing, so that the optimal result can be achieved. The journal articles also provided examples of cost benefits of using recycled materials in other regions around the world that would work if policies and other strategies were implemented.

Government involvement

The Province, Metro Vancouver and local municipalities are actively involved in recycling of construction and demolition waste which is apparent through their releases of various documents with current technologies and methods of recycling, change or introduction of policies related to recycled materials in construction, guidelines and best practices, and a variety of other activities. Vancouver has its own street restoration manual (City of Vancouver) that is an excellent manual for the standards, specifications, and procedures for construction on city streets that ensures the safety of all that use the streets.

A large challenge to quantifying the value of using RAP and RCA in local road construction is the lack of available data. Local municipalities do not typically track or publish the quantity of recycled material used in road construction. Some municipalities have specifications which allow for a certain percentage of RAP, but since the cities typically hire a contractor to install the road, unless they require that percentage or request the information from the contractor, they have no way of knowing exactly how much recycled material is used in their roads; they only know that it is less than the maximum allowed amount (Storry). The BC Ministry of Transportation and Infrastructure (MoT) published a document which indicates the costs of different city projects for different construction rehabilitation projects throughout British Columbia (Ministry of Transportation and Infrastructure). The BC MoT document provides total costs with an attempt to break them down into major categories: management, engineering, construction, but not the level of detail as separate materials cost as seen in Figure 2. Tracking of the total material costs for projects would allow road owners to better assess the economic benefit of switching from virgin to recycled material.

All the journal articles reviewed that touch on the structural integrity specifics, (Paranavithana and Mohajerani; Foth, et al; Alam, et al), of construction jobs such as the increased use of a recycled material in a mix, or increased RAP in asphalt mix for pavement, use general percentages that the researchers choose as a guideline rather than specific percentages from a municipality which are less available. The general principle that the MoTI follows in RAP use in construction and rehabilitation projects was

[1] This is the method where a machine goes over the road while heating the asphalt, remixing the asphalt, and then re-laying the asphalt while compacting it using the same materials. (Some new materials may be put in to strengthen the road)

mentioned previously; BC's rule in RAP percentages for binder course and surface course in primary and secondary roads.

planning	$119,300
project management	$263,200
engineering	$685,400
construction	$3,849,600
other (default)	$14,100
Total calculated costs	$4,931,600
Cost per lane km	$127,103

Figure 2 Example of a cost breakdown from the document that the Ministry of Transportation and Infrastructure released in 2013 (Ministry of Transportation and Infrastructure)

Canada's national infrastructure deficit alone is estimated to be $44 billion and 79% of the life span of the public infrastructure has been spent (Alam, et al). The life of many of Canada's roads are coming to an end and are up for a renewal. The federal government announced a budget of $12 billion Canadian dollars in 2009 and that will not be enough for perfect infrastructure conditions Canada wide, roads included, and this means that economic consideration needs to be closely evaluated. This could be a key leverage point to Metro Vancouver's goal of increasing the use of recycled materials.

Since money is saved by using recycled materials that follow industrial and provincial standards, there will likely be an increase in demand for recycled materials not only because of cost benefits but also because of environmental benefits as well. By switching to a higher percentage use of recycled materials in their construction, Metro Vancouver could become an example for Canada that could possibly increase the support for this such practices on a national level. The reuse and recycling potential of construction and demolition waste has been recognized, but not fully utilized (Alam, et al). For Metro Vancouver to meet their diversion targets, that needs to change. According to the Transportation Association of Canada (TAC) Best Practices Guide for the Use of Recycled Materials in Transportation Infrastructure, there is no formal policy requiring the recycling of excess or by-product material from any project. Given the potential impact of such a policy, it should be a primary target for adoption.

Recycled Concrete Aggregate (RCA)

RCA is produced through the crushing of demolished concrete sources and differs from fresh virgin material due to the cement paste attached to the original cement. The highly porous cement paste contributes to the lower density, higher porosity, and therefore higher water absorption providing a variety of attractive qualities for RCA (Paranavithana and Mohajerani). RCA is most frequently used in highway construction (Donalson, et al) as well as concrete pavement projects. The use of RCA in new projects and even the rehabilitation of projects has been demonstrated to save money, save time, and even reduce the environmental impact of projects (Garber, et al).

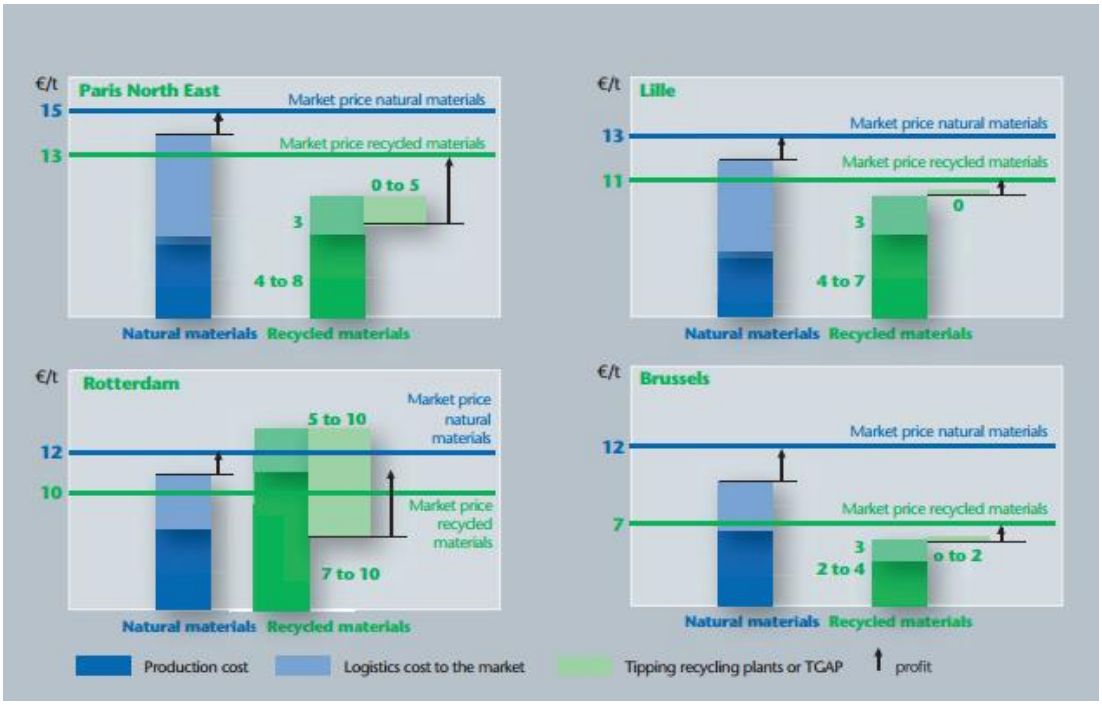

Figure 3 Example in Europe of the affordability of recycled materials compared to virgin material. They have other constraints such as lack of resources or limited possibilities for disposal however through policies in place because of that they have been able to cheapen recycled materials to make it affordable (World Business Council for Sustainable Development).

There are few examples to be found in British Columbia for the analysis of using RCA in construction however, there are more from other parts of the world. One example is Winter Haven, Florida where the use of RCA in highway construction was compared to Virgin Limerock Aggregate (VLA). According to the study following the appropriate construction criteria and specifications, the use of RCA was cheaper than using VLA. An important criteria to be considered in this analysis is that the VLA required an extra 30 miles of transportation. This is important to take into account because transport is a large portion of the cost of aggregate for construction projects due to its relatively high weight. In cases where VLA is closer to the site, the VLA may be cheaper than RCA.

Another interesting factor that was used in the cost analysis was the Life-Cycle Cost of the materials that included annual maintenance cost and length of product life; if the two values differ then this factor had to be included in the analysis (Donalson, et al). The length of product life does not only include the material durability but also construction that results in dredging up of the road such as installing new piping or other projects. In Metro Vancouver where growing cities require removal of surface layers and base layers to install and repair utilities beneath the road, the product life is likely shorter than rural roads. Therefore, the durability of the materials would be of less importance since the possibility of changing or removing the material in the short term would be highly likely. This does not change the fact that the basic standards for material quality needs to be followed. For areas expected to have future changes that requires roads to be replaced over and over again, then material durability specifications could be relaxed as long as the material still complies with the basic standard for road users. Relaxing durability specifications would save money while still using recycled materials. What needs to be considered is that the constant use of new materials will dramatically increase the cost in the project where if the materials dredged up are reused there can be significant savings.

	Recycled Concreted Aggregate ($USD per ton of aggregate)	Virgin Limerock Aggregate ($USD per ton of aggregate)
COST OF MATERIAL		
Delivered Price (DP)	12.75	13.20
Price of Raw Material, F.O.B. (RM)	0.00	2.00
Cost of Processing the Material (PR)	3.00	3.00
Cost of Stockpiling the Material (ST)	0.50	0.50
Cost of Loading the Material (LD)	0.50	0.50
Cost of Transporting the Material (TR)	2.75	6.00
Profit (P)	6.00	1.20
COST OF INSTALLATION		
Cost for Design of Application with Material (DR)	0.00	0.00
Cost for Construction with Material (CC)	3.75	4.50
Cost of Testing and Inspection for Proposed Application (RP)	0.70	1.00
Sub-Total Cost of Installation (CI)	4.45	5.50
LIFE-CYCLE COST		
Annual Effective Cost (EC)	1.66	1.82
Cost of Installation (CI)	4.45	5.50
Capital Revovery Factor (CRF)	0.15	0.15
Annual Maintenance Cost (AM)	1.00	1.00

Figure 4 Comparison of RCA and VLA showing the economic benefits of using RCA in the construction in Winter Haven, Florida (Donalson, et al).

Lock Block is a local company that creates high quality concrete aggregate from recycled concrete with an annual capacity of 600,000 tonnes (Ammerlaan). This is 46% more than the total annual construction and demolition concrete waste from all of Metro Vancouver. It is apparent that end markets, not processing capacity, is the key barrier to increasing use of recycling material in the road construction. In order to improve end markets, Metro Vancouver's member municipalities could work with a local recycling companies. Municipalities could provide material to local recyclers for processing and then they could use their own material in their projects instead of virgin or recycled material from unknown sources. Such a working cooperation would likely save municipalities' money compared to purchasing virgin aggregates. For the concrete waste to be recycled locally, there needs to be a market for 100% of the recycled feedstock; all the waste concrete going into the local recycling facilities needs somewhere to go when it has been processed; otherwise, it may simple become a large stockpile on a local recyclers property.

Once local recyclers establish markets for their existing products such as RCA, they will be better positioned to tackle other road recycling challenges such as asphalt as well further contributing to the regions waste reduction initiatives. Since incorporating a new materials requires time and money, in the short term, recyclers may want to consider other ways to diversify their portfolio such as other concrete services, road installation, and pavement laying in order to raise the capital to invest in further recycling initiatives.

Similar to the RAP example in the city of Hamburg, Germany below, a standardized system with one company in the early stages of implementing a new policy on using RCA, could be more effective than having several different contractors with varying material quality throughout their region. Adopting a

similar approach in Metro Vancouver context could allow Metro Vancouver's member municipalities to benefit from both scale and quality through combined purchasing agreements. This would also allow local municipalities to improve standardization of projects throughout the region rather than undertaking separate projects with multiple contractors. For example, Metro Vancouver could act on behalf of its member municipalities to negotiate aggregate prices. Or two or more member municipalities could co-purchase material or processing machinery. One of Metro Vancouver's goals, is to increase the amount of recycled materials used in construction and rehabilitation. For this to successfully and sustainably happen, there needs to be adequate demand for recycled materials, created through policy if necessary, until a mature market is in place to support recycled material use.

Recycled Asphalt Pavement (RAP)

RAP is the reclaimed material from roads and other surfaces that use bitumen in conjunction with aggregates to create asphalt. There are several different ways for the creation of RAP, some are done in place of the construction site, such as on a road for rehabilitation, where techniques such as hot in-place asphalt recycling[2] and cold in-place asphalt recycling[3] (InfraGuide). When the material is taken away to a recycling facility, the asphalt undergoes a similar treatment as concrete where the material is crushed, screened, cleaned, and sorted to be used again. The main use for RAP are roads and surfaces in urban areas such as parking lots. The use of RAP in construction also saves money, time, and resources if done properly following the right standards for the practice. Hot in-place technologies in BC alone have been used on over 30 million square meters of highways and paved side roads using 80% RAP and being comparable to that of new hot mix asphalt[4] while having cost savings of up to 50% over virgin materials use (Finlayson, et al).

RAP that is stockpiled at various locations unaltered could be molded into preset forms to prepare for repairs around Metro Vancouver. The city of Pittsfield, Massachusetts, has "blacktop cookies" (Baystate Roads Program) created to fix their potholes by simply reheating the cookies, placing them, and compacting them. This method of fixing potholes is less expensive and less labor intensive than using conventional methods (Michigan's Local Technical Assistance Program).

BC allows for 15% RAP in surface course for primary roads (highways and high volume roads) and 30% RAP in the binder course. In secondary roads, 30% RAP can be used for the surface course and 100% in the binder course. This does not mean that all construction and rehabilitation is done this way but rather that this can be legally done following the proper guidelines. Since municipalities hire contractors to do the work for them and the municipalities do not make it the norm to request the completion of work specifications, there is not always the confirmed knowledge that the complete material used was recycled but rather that it was the percentage allowed or less. Strict monitoring of the percentages of RAP used in construction and rehabilitations is one area that offers an opportunity for improved recycling performance.

[2] This is a technique where a machine is placed over the road that heats the asphalt pavement, scarifies it, mixes it with added virgin material if necessary and binding agents to help with the relaying, lays it, and then compacts it all in one motion.

[3] This technique is similar to hot in-place but instead of heating the asphalt, it instead goes straight to scarifying it and using an emulsification agent to then compact it once again.

[4] This is the term used for fresh asphalt ready for road laying or other construction using virgin material – not to be confused with recycled hot mix asphalt which the name indicates, is used with recycled asphalt.

If a single contractor is awarded a bid for a startup period of time for municipalities that have a co-purchasing agreement (potentially 3-5 municipalities rather than all 22 municipalities together), then monitoring specifications of the work profile would be easier. Having all the information from the construction project and breakdowns of the material use would allow proper management practices and analysis for further research and development of the recycling technologies. A great example of this can be found in Hamburg, Germany where the City decided to increase its RAP usage from less than 50% to 100% in the resurfacing of its roads (Denck). The City directly approached contractors to come up with a solution for this that followed the City's sustainability criteria. By approaching the contractors directly, the City greatly increased the chance of success of the ambitious project (Denck). The company STORIMPEX AsphalTec GmbH was awarded the contract which saved the City 30% in comparison to the conventional means of road surfacing and rehabilitation (Denck). The policy for this 100% RAP use is a concept that is validated for full scale implementation meaning it is soon ready to be used (Denck).

Hamburg has a population of around 1.8 million and Metro Vancouver has a population of 2.4 million; the populations are of similar size with Metro Vancouver having much more area than Hamburg, 2,882 sq/kms compared to 755 sq/kms. It can be assumed that there is a similar volume of cars on roads in both cities and that the quality of roads should be similar with the major differences being climate. The methods incorporated in Hamburg for 100% RAP usage has the potential to offer similar advantages for by Metro Vancouver.

To further strengthen the idea of 100% RAP usage, there are further examples in the literature, including one that focuses on the technologies for such RAP usage with plant technologies that have successfully done so (Zaumanis, et al).

Recommendations

The research has concluded that the major barriers to introducing new standards that would increase the use of recycled materials in construction are regulatory and perceptions with related to technical aspects. The reason why the technical issues are highlighted as a barrier is because although research and development has come so far for both RCA and RAP, where 100% RAP can potentially be used (Zaumanis, et al), and 50% RCA in green concrete mixes that follows industrial standards already (Alam, et al), there are still persistent misconceptions as to their performance. To have RCA increased to 100% in mixes and used as an industrial standard with 100% RAP, there needs to be a concentrated effort and focus by the government and industry on the development of policies and demand.

Below are some recommendations that this research has found could be implemented not only to increase the use of RAP and RCA but to produce for cost savings, and support environmental sustainability:

- **Minimum percentages in purchasing agreements**. Follow an approach similar to the Hamburg, Germany example, to stimulate innovation, and quality for road rehabilitation and construction using a high amount of RAP as well as RCA as part of the purchasing requirements. Much like fly ash in concrete.
- **Municipalities could co-purchasing recycled material for road construction.** Metro Vancouver member municipalities could collaborate to co-purchased or co-process recycled material for road construction. By providing material to processors or processing their own

material, municipalities could have better information about the source of the recycled material.

- **Adopting clear process for piloting and documenting recycled material road construction**. Several contractors in the region use or have tried using recycled material in road construction projects. Creating a clear process for how industry can pilot recycled materials and determining in advance what kind of technical information needs to be documented to encourage more widespread adoption would help provide better information on the performance of recycled material. Proper guidelines should be followed so that high percentages of recycled material use for both primary and secondary roads with proper monitoring and documentation. Standardized monitoring and documentation are key to filling the knowledge gap regarding recycled material performance.
- **Industry could adopt circular economy practices**. What goes into a road construction project stays there and is reused in future refurbishments. For this to happen effort has to be made so that the quality of the material going in can more easily be processed and reused. For example if the recycled asphalt pavement in a road is of the same or better quality than virgin material, which is possible, then using HIPAR (Hot In-Place Asphalt Recycling) or similar methods would be easier and additional agents for the mix can be negated. This can also be applied to other infrastructure – preparing the construction for repurposing or rehabilitation – preparing for future developments/construction/rehabilitation. Also, Material providers could look at options for leasing material to municipalities opposed to selling it. The idea being to create contracts which would require the material to be returned to the material provider at its end-of-use so that it can then be used in another construction project.
- **Provincial policy changes**. Instead of having a "best practices" method where there is an option of using recycled materials in construction, there should be a mandated policy where it is required by whichever contractor or contractors are hired. The policy would obligate contractors to use an amount of recycled materials of the proper standards which is then monitored and reported back to the municipality for data archiving so to better understand what is being used and how much and how it is performing in the long run for better analysis when required.
- **Support Innovation** Provide industry confidence to invest in new recycling technologies. To further their R&D of technology for more efficient use of recycled materials, local companies need to be able to justify their investment in new technologies such as Ecopave Systems or Falcon Road Maintenance Equipment. Policies mandating a minimum use of RAP and longer term purchasing contracts, would encourage industry to invest in recycling technologies.
- **Preparing stockpiled materials to make them more market friendly.** The recycled materials that have been prepared and are stockpiled should be prepared in a way so that they can easily be used for a function without further processing or manipulation. An example for this with RAP would be to create blacktop cookies in preparation for pothole filling. Having blacktop cookies ready for repairing at various locations around Metro Vancouver would be valuable so as to rapidly respond to nearby fix requirements.

Future Research

The scope of this research is limited. Since this paper is purely based on extensive literary review, it would be useful to expand the research using interviews conducted with industry professionals and municipal representatives with insight to the topic. Another potential avenue for research could be into the technical aspects of the topic with special attention to the research and development into the future possibilities for recycled materials. Finding out the latest research on mechanisms to increase the percentage use of recycled materials in prepared mixes for constructional use would be beneficial in designing policies that support the environmental and economic benefits for Metro Vancouver through further diversion of recycled materials from landfills and stockpiled recycling facilities.

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