Diverting Landfill Waste:

Understanding the Barriers to using Recycled Concrete Aggregate in Metro Vancouver

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

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Executive Summary

Due to the slowing end-use market for recycled concrete aggregate (RCA) in Metro Vancouver concrete recycling facilities are at limited capacity to accept concrete waste. As a result of this, concrete waste is not being recycled and re-uesd. Instead, it is being stockpiled at recycling facilities, and may be ending up in landfills outside the region. With concrete waste making up about one-third of Vancouver's total waste, this is an issue that needs to be addressed.

This report first identifies what the main barriers are to increasing the market demand of RCA in Metro Vancouver, and second recommends a number of actions that will help alleviate the identified barriers. This information is intended to help Metro Vancouver develop policy which will increase the use of RCA, and ultimately eliminate any concrete from entering landfills.

Barrier	Description	Recommendation
Regulations	The regulatory climate in BC restricts the use of RCA within many aggregate applications. In particular, the provincial and municipal specifications for concrete construction exclude the use of RCA for any high-level applications.	Change provincial construction specifications to reflect the end product strengths, rather than specifying what material and techniques are appropriate for use.
Perception	The perception of RCA's fitness in construction applications varies greatly from group to group. Some, see it as a great product, while others do not feel that it meets the requirements for construction.	A government-led pilot project that showcases the fitness of RCA as a suitable construction material. An excellent example would be the use of RCA in the new proposed Evergreen transit line.
Market	The vast abundance of virgin aggregates in BC keeps the cost of aggregates in the Province low, thus making the difference in price between RCA and virgin aggregates small.	Increase the tipping fees for C&D waste.
Technical	There are limitations to the amount of RCA that can be used. This is due to the mortar content of the RCA.	Introduce industry standards for crushing, sorting, and cleaning recycled concrete.

The extent of this study has been limited due to the fact that there were no interviews conducted with municipal or provincial government representatives. However, this further highlights a common *complaint* from industry representatives: that communication with these levels of government, on this issue, is difficult to establish. Future research into how these communication networks can be strengthened would serve both the industry and different levels of government well.

1. Background and Benefits to using RCA

In Metro Vancouver it is estimated that 1.3 million tonnes of construction and demolition (C&D) waste is generated annually (Kane Consulting et. al. 2012). Mineral aggregates constitute 34% of that total waste, with concrete making up the bulk of this material (Ibid.). A large part of this concrete waste is diverted away from the landfill for recycled use. RCA has many different end-use applications, and can be a lower cost alternative to using virgin aggregates (VA) in concrete construction (US DOT 2004).

Overall project costs can be reduced as less landfill fees are paid on C&D waste due to the recovered material. Project costs can also be reduced through less transportation of virgin materials. Since C&D waste is usually found near urban areas, and also in close proximity to new development projects, the distance that the aggregates need to travel is reduced. As well, once infrastructure is established, then mobile sorting units and dedicated recycling facilities can provide good returns (WBCSD 2012). Figure 1 below illustrates the decreased bottom-line price of RCA in four European markets.

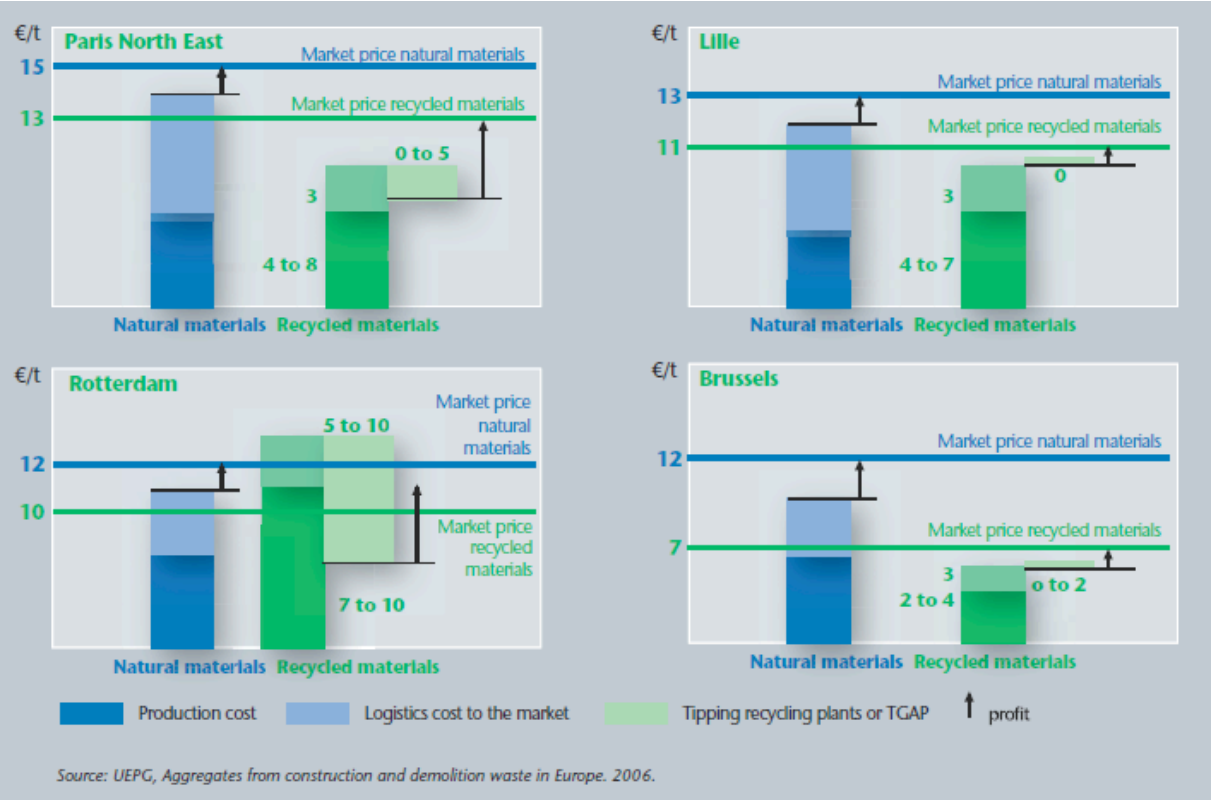


FIGURE 1: Each case above has a limiting factor which is increasing the price of VA. Paris, for example, has little access to natural aggregates. Note that the tipping fees vary greatly, and locations where tipping fees are the largest also hold the greatest amount of profit for using RCA. (WBCSD 2012).

However, end-use markets for RCA are currently slow in Metro Vancouver. The five concrete recycling facilities in the Metro Vancouver region are currently processing as much RCA as those end-use markets for RCA can absorb (Tawfik and Shishido 2012). United Lock-Block alone can process 300 tonnes per hour of used concrete, with an annual capacity of over 600,000 tonnes, which is 46% more than the total annual C&D concrete waste from all of Metro Vancouver (Kane Consulting et. al. 2012).

Like most other demolition, land-clearing and construction (DLC) recycling facilities, it is the end-market demand, and not the physical capacity, which is constraining their ability to accept more material (Tawfik and Shishido 2012). As a consequence the recycling facilities are sometimes unable to accept all the concrete waste available which results in concrete being taken to the landfill (Kane Consulting et. al. 2012). Specifically, it is the lack of demand for road base that causes the facilities to shut down during busy periods. Concrete recyclers assert that the British Columbia Ministry of Transportation has refused to purchase any of their road base, and instead uses only VA (Kane Consulting et. al. 2012).

2. Methods

This study is informed through two methods of analysis. First, a literature review was conducted to develop an initial list of barriers and benefits of using RCA as a construction material. Second, I conducted a series of semi-structured interviews with stakeholders associated with the concrete construction and demolition industry in Metro Vancouver.

Beginning with the technical issues I consulted engineering journals to understand the fitness and feasibility of RCA as a building material. The regulatory barriers were informed through a review of building specifications for road and highway development within British Columbia, as well as through the United States. Market Barriers were identified within two key documents: the first is Kane Consulting's (2012) study which aimed to understand the supply chain of used building materials in Metro Vancouver; the second is G.E. Bridges & Associates Inc. Consulting Economists (2004) paper which provides an overview of the Western North American market for BC construction aggregates. Finally, the perception barrier was informed through a number of lateral documents that aim to understand sustainable procurement strategies and behaviour, as well as popular media sources that have written articles on sustainable construction and the sustainability of concrete (McKenzie-Mohr 2011; Pruess and Walker 2011; Sourani and Sohail 2011). With this literature review I was able to create a list of compelling questions that would fill in the unknown aspects of the barriers. These questions were then used to conduct semi-structured interviews.

The semi-structured interviews are the only primary research that was conducted through this study. A snowball sampling method was seen as the most effective way to gain the research participants. In total fifteen informants were contacted. Of those fifteen, seven responded with interest in participating in the study. One of the seven declined on participating in an interview; however, they were able to share information through email conversations. In total, six interviews were conducted. Each interview varied in time from thirty minutes at the shortest, to over two and a half hours at the longest. The appendix contains a list of interview questions.

3. Barriers for increasing the use of RCA

Below I have listed the four groupings of barriers which have been identified in this study. They are presented in the order that the interviewees ranked from most important to least: Regulatory, Perception, Market, and Technical (Drew 2013; Anonymous informant 1; Anonymous informant 2; Anonymous informant 3).

3.1. Regulatory

Regulations have dramatic affects on the use and production of materials in the construction industry. Currently in BC the regulatory climate for using RCA is very restrictive. BC highways do not allow RCA to be used in new road and highway construction (British Columbia 2012). This is also reflected in municipal construction. The MMCD (Master Municipal Construction Documents) specifications state what materials and techniques are appropriate for concrete construction. Through every interview that was conducted, this is **the number one barrier** which is seen to be limiting the use of RCA in Metro Vancouver (Alam 2013; Drew 2013; Anonymous informant 1; Anonymous informant 2; Anonymous informant 3).

One example of how regulations can change the use of a RCA can be seen recently in Abu Dhabi. Regulations were passed that require 40% of the aggregates used in road construction to be RCA (Overdahl 2013). The writing of these new specifications created a sudden demand for RCA which brought a concrete recycling plant back to life. Previously, this recycling plant had over 1.6 million tonnes of material waiting to be crushed when it shut down due to a complete lack of market demand for RCA, and now, due to the new specifications, they are facing orders of over 2 million tonnes of RCA (ibid).

This strongly reflects the situation here in Metro Vancouver. At the moment most of Vancouver's facilities are unwilling to take more material to recycle. One of the largest concrete recycling facilities, for example, is stockpiling over 250,000 tonnes of concrete waste in its yards (Anonymous interview informant 2013). This shows the importance of increasing market value for RCA through specifications in road and building construction.

Moreover, due to the oversupply of concrete waste, and under-demand for RCA, recycling facilities restrict the amount of waste that they can accept. This creates further regulatory issues that must be addressed. The Agricultural Land Reserves throughout Delta are becoming a frequented site for contractors to dispose of their C&D waste. This is done through agreements with farmers on their plots of land, whereby the waste is used on the farm as 'fill' (Loo 2013). Farmers see it as an easy way to make some money, or perhaps some free material for construction, on their land. Currently the regulation enforcing what can be used as fill for road base on these farms allows C&D waste up to 18'' in size, rather than the ¾'' that is often the end processing goal of RCA. Most notably is the use of these C&D wastes for cranberry farmers who have the need to create large dykes around their crops (ibid). The poorly regulated nature of this use of C&D waste does not account for contaminants within the C&D waste, such as the leaching of petrochemicals from recycled asphalt onto what has been set aside as agricultural land.

3.2. Perception

Although RCA has proven its fitness technically through engineering studies and practical use elsewhere in the world, many people still see it as an inferior product, and are unwilling to use it in construction. This kind of resistance is often met when more sustainable practices require a change in behaviour. “sustainability requires new ways of thinking, methods, practices and attitude. Hence, it requires change. But as normally happens when implementing a new initiative; there is a resistance to change. This problem may exist at all levels […] Unfortunately, the voluntary nature of the codes of

practice can be seen by the different parties as an excuse for not initiating change in a sustainable direction." (Sourani and Sohail 2011, 234-5).

This poses a much larger barrier than technical issues, or even market issues. If people truly believe that RCA is an inferior product to VA, then there will be no willingness to change behavior. The negative perception of RCA is seen to be largest from government engineers (Drew 2013; Anonymous informant 1 2013; Anonymous informant 2 2013). This is a major challenge, as these are the users who are creating the specifications for concrete construction, and without their full support RCA will not see its full potential reached on the market. However, not all municipalities are resistant to using RCA for construction and road building (Anonymous informant 1). Some are already using it, and are progressive about adding other recycled materials to their paving mixes (ibid).

Technologies are constantly changing and improving the efficiency and efficacy of construction, however, these technologies are felt first through industry, where they are developed, and then slowly trickle into the methods that the government supports (Anonymous informant 1 2013). A major concern from one interviewee was his belief that these specifications will not change until there is a "changing of the guard" (ibid). What he means is that because certain engineers have experimented with trials using RCA ten or twenty years ago and found that it was not technically feasible, they are now set in their view that it is not a good product for construction (ibid).

3.3. Market

The long-term trend in Western North America is that virgin aggregate prices are steadily increasing (G.E. Bridges & Associates Inc. 2004). This is due to a reflection of land ownership restrictions, high costs in mining and transportation, and difficulties in obtaining regulatory approvals (Ibid). These are factors that increase transportation distances, which in turn drive up the costs of delivered aggregate. Not to mention, VA are a finite resource, and there are only so many locations left that are suitable aggregate mines. All of these reasons suggest that RCA is becoming a much more attractive alternative to VA. However, the situation in BC is somewhat unique, in that there currently are vast supplies of relatively cheap virgin aggregate on the market (Kane Consulting 2012).

The market for RCA is currently low, and this is reflected through the concrete recycling facilities in Metro Vancouver who are currently at full capacity and unable to move their supplies of RCA out of their storage yards (Ibid). Although the price of RCA is lower than VA in Metro Vancouver ($7-$14/tonne for RCA, while VA cost from $15-$24/tonne), the relatively low cost of VA in terms of the total construction costs is quite low (Anonymous interview informant 2013).

3.4. Technical

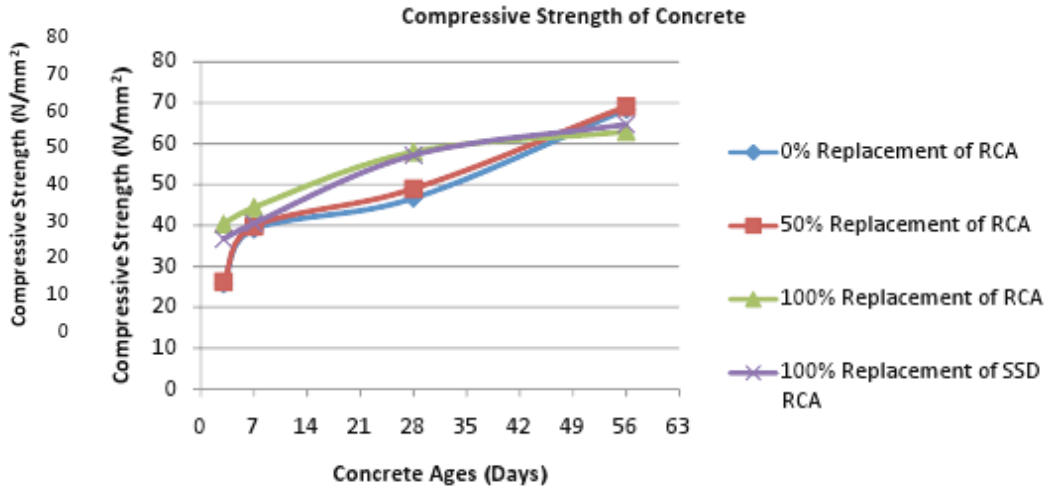
The technical barriers for using RCA are divided into two categories: structural fitness and the source of the recycled material.

3.4.1. Structural fitness

There is a strong consensus among engineering literature that RCA can meet structural fitness for a number of concrete applications (Zhang and Ingham 2010; Iqbal and Quiasrawi 2012; Limbachiya et. al. 2000; Kumutha and Vijai 2008). This fitness is dependent upon a mix of up to a maximum of 25%

RCA to VA. The use of RCA does not have a diminishing effect on compressive strength[1] (see figure 2), although, the flexural strength[2] decreases with the amount of RCA used. So applications such as roads and highways, concrete blocks, and curbs would be appropriate for even large amounts of RCA (De Juan and Gutiérrez 2007; Kumutha and Vijai 2008; Limbachiya, et. al. 2000).

FIGURE 2: As VA is replaced by RCA there is little to no decrease in compressive strength of the concrete. (Yong and Teo 2009).



3.4.2. Source of the Recycled Material

The major difference between RCA and natural aggregates is in its composition: it is comprised of both natural aggregates, and cement mortar (Iqbal and Quiasrawi 2012). Only RCA with a mortar content under 44% can be used for structural concrete, as the mortar affects the bond of the new concrete (Juan and Gutiérrez 2007). As well, the source of the concrete is sometimes unknown, and only RCA sourced from high-strength concrete is suitable for creating new high-strength concrete construction (Limbachiya et. al. 2000). Using aggregates from selected materials and industrial by-products greatly increases the potential for use in concrete and/or as road construction materials (Cement Concrete & Aggregates Australia 2008). On site crushing would be one possible solution for dealing with source issues. However, one study pointed out that appropriate technology for on-site crushing is currently not available (Marinković et. al. 2010). This is in part due to the inability to wash/clean the aggregates. As well, space is an issue when considering on-site crushing. If you are dealing with anything in the city then it is likely not going to be enough room to crush and stockpile the material until it is needed for the appropriate phase of building (Anonymous interview informant 2013).

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1 Compressive strength: compressive strength is the capacity of concrete to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Compressive strength test results are used to determine if the concrete mixture meets the requirements of the specified strength. Requirements can vary from 17MPa for residential concrete, to 28MPa and higher in commercial structures (NRMCA 2003).

2 Flexural strength: Flexural strength is a measure of concrete's resistance to failure in bending.

4. Recommendations

Below is a list of recommendations for Metro Vancouver to pursue when considering how to increase the market demand for RCA. The table below may be used as a quick reference of the barriers and recommendations associated with each barrier. Further discussion about the details of each recommendation follows.

Barrier	Description	Recommendation
Regulations (section 3.1)	– MMCD Specs. – MoT's Road building Specs. – Disposal of concrete waste in ALR	Target changing specifications for construction/road building as immediate priority.
Perception (section 3.2)	– Lack of confidence in using RCA as a construction material – Insufficient link up between technologies and specifications	A government-led pilot project that showcases the fitness of RCA as a suitable construction material.
Market (section 3.3)	– Relatively low cost of VA in terms of overall construction costs	Increase the tipping fees for C&D waste.
Technical (section 3.4)	– Limitations to the amount of RCA that can be used in a mix – Uncertain mortar content in RCA.	Introduce industry standards for crushing, sorting, and cleaning recycled concrete.

4.1. Recommendations for Immediate Action

The most pressing and immediate concern should be on getting the MMCD and MoT specifications for road and building construction to reflect the available technologies and techniques to the concrete industry. However, there are a number of smaller actions that must take place for this change to happen. These are listed below as needing immediate action:

4.1.1. Support the existing market for RCA through education.

There already exist a number of avenues for RCA outside of concrete construction. These include, but are not limited to:

- Non-specification block concrete: United Lock-Block is one example of a business that has created a high-quality product from recycled concrete

- Landscaping: there are a number of uses for landscaping including fill, drainage, and decorative material (Anonymous informant 1 2013).
- Septic sand: RCA sand creates good quality C-33 septic sand. The lime contained in the mortar is a good agent for increasing the speed at which the waste is broken down (Drew 2013).

Supporting these options through education and outreach would help to bring awareness to the possibilities for recycling concrete (Alam 2013).

4.1.2. Government-led flagship project which champions the fitness of RCA

There are a number of options that exist for a large construction project which will showcase the fitness for RCA. Currently UBC-O's Dr. Shahria Alam is building partnerships with government to implement a large scale RCA project (Alam 2013). It is important that this project is high-profile and reaches a variety of media sources to build public understanding and support for using RCA in buildings. Some examples of potential projects include the newly proposed Evergreen sky train line, and an excellent source for the material for the project could be attained from the old Port-Mann Bridge (Drew 2013).

4.1.3. Create stricter regulations for C&D waste being used for roads and fill in Delta's A.L.R.

Thomas Loo, the compliance officer for the Ministry of Land and Agriculture, would be a good contact to start negotiations and understand the finer details surrounding this issue. The roads and fill used should be purchased from a processing plant, and of a particular gradation (Loo 2013). The dumping of C&D waste on ALR property should be prohibited. This will encourage more of a market for the recycled concrete processing facilities, and reduce the likelihood of contaminated waste leaching onto farmland.

4.2. Recommendations for Medium-Term Action

The following recommendations are for medium-Term considerations (1-3 years).

4.2.1. Change MMCD and MoT Specifications for RCA use in construction and road building

Specifications are currently limiting the type of material that may be used, as well as the techniques to use. In the future, specifications should reflect the end product goals – such as the strength and longevity of the structure. This should also be reflected in the RFT (request for tender) agreements that are offered to commercial operators (Anonymous informant 1 2013).

4.2.2. Increase tipping fees for C&D waste

Increased tipping fees will act as a strong disincentive, and may convince demolition companies to consider recycling as a better option. As well, according to Figure 1 of this report, it increases the profit attainable through using RCA as opposed to VA (WBCSD 2009).

4.2.3. Introduce standards for concrete recycling and processing

Currently the main technical issue with using RCA as a building material is the mortar, and its associated 'dust'. However, with more rigorous processing much of the mortar dust can be removed and RCA can be as good, or better a product than VA. United Lock-Block, a richmond-based company,

is an example of best practice in this field. The principal has invested in upgrading their technologies to incorporate crushing, sorting, and most importantly cleaning into the processing steps for RCA. A standard procedure for processing RCA would allow for a standardized product (Drew 2013).

4.3. Final Recommendations

This research will act as an appropriate starting point to addressing the issue of RCA's market demand. However, RCA is only one by-product of concrete waste, and there exists two other avenues which need to be explored: Recycled Asphalt Pavement (RAP), and Recycled Asphalt Concrete (RAP-CON). RAP has already been targeted by MoT's 2012 specifications, and is slowly being introduced. However, RAP-CON poses a number of greater challenges, and is far more difficult to deal with as far as recycling than either just concrete (such as RCA) or just asphalt (RAP) (Anonymous informant 2 2013). Further research into dealing with this issue is required.

As well, there is a strong feeling of hypocrisy towards some municipal governments from industry regarding the use of RCA in construction. Although this is not felt towards all municipalities, as some are much more progressive in their use of recycled materials than others, it is an issue that requires attention. It is the sentiment of industry that some municipalities are using products such as RCA, and even RAP-CON, in their projects, and meanwhile, they are prohibiting industry from using it as a building material even in municipal contracts (Anonymous Informant 1 2013; Anonymous informant 2 2013). However, a strong bias exists in this research, as there were no interviews conducted with municipalities throughout Metro Vancouver. There exists a difficult balance between liability, cost, and safe durable infrastructure which government engineers must take into account when deciding on which materials are appropriate for specification.

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6. Appendix

Interview questions

Sample questions for semi-structured interviews

Technical Barriers

What is the purpose of RCA in construction?
What has been your experience in working with RCA?
Is RCA a suitable alternative to using VA for a variety of higher-level construction purposes?
Where is the recycled concrete sourced from that is used for RCA?
Is this a concern, and what are some ways of dealing with this that would ensure you knew where the RCA is sourced from?
Are there appropriate technologies for crushing, sorting, and cleaning on site to create a high quality RCA?
Is it common that construction companies see the use of RCA as inferior to virgin aggregate?

Regulatory Barriers:

What is unique about the specifications for RCA within British Columbia? Metro Vancouver?
What are the regulatory barriers that you see limiting the use of RCA in Metro Vancouver?
Is the regulatory climate in BC likely to change in response to the changing specifications in other countries? And if so, then why?
Do you think that regulations are lagging behind in BC due to a perceived notion that RCA is inferior to virgin aggregate for concrete construction?

Market Barriers:

How does the price of virgin aggregate compare to that of RCA?

What are the factors which are causing the fluctuations, or the dampening, in the RCA market?

What has the market for RCA been like in the past? And where do you see it going in the future?

What can be done to strengthen the market for RCA?

If RCA was overall a cheaper alternative to using virgin aggregate, would that change buyer's procurement strategies, and allow them to adopt a stronger appreciation for RCA as a suitable material for concrete construction?