AN INTEGRATED APPROACH TO SUSTAINABILITY FOR THE CONSTRUCTION SUPPLY CHAIN- A WASTE-TO-RESOURCE STRATEGY

G.L. Low
Centre for Sustainable Buildings & Construction
Building and Construction Authority of Singapore

EXECUTIVE SUMMARY

For the construction industry, an industry which is often perceived as fragmented, a coordinated and integrated approach similar to the supply chain management concept could bring about synergy among key industry players; develop their capabilities and potential, thus making it possible to implement initiatives for the benefit and development of the whole industry.

The Building and Construction Authority of Singapore (BCA) developed a strategy on recycling and reuse of concrete aggregates and adopted integration among key players in the construction supply chain- namely the demolition contractors, construction and demolition (C&D) waste recyclers, ready mixed concrete (RMC) suppliers, building contractors and developers, for the benefit of the whole construction industry.

This paper shows that an integrated waste-to-resource approach to recycle potential building materials for the industry could result in a sustained supply and demand of sustainable construction materials, thus contributing to Singapore's goal of achieving environmental sustainability.

Key words: integration, waste-to-resource *approach, recycled concrete aggregates, sustainable, construction/ materials supply chain, systems approach*

CURRENT SITUATION

The construction industry in Singapore is characterised and composed of numerous small to medium sized enterprises. It is fragmented by nature of its operation and the mechanism of the market forces- each enterprise is often 'disconnected' from one another, operates independently with little or no synergy among them; and because competition is intense, the players are skeptical of sharing information or resources and therefore supply chain integration or management practices are difficult to be realised in this industry.

For Singapore the construction materials supply chain is heavily reliant on imported raw materials. As such it is subjected to influence from global market forces. Uncertainty in the supply of materials is a reality and material prices fluctuate according to global demand and supply, which in turn affects project costs. Therefore to enhance the resilience in the supply of essential construction materials, which is of strategic importance to Singapore's economic development, the adoption of sustainable construction becomes crucial as it looks at the efficient usage of raw materials in construction, reduction of waste, and waste recycling.

As natural resources deplete and more technological means are available to convert waste into useful materials for various construction applications, it is timely and worthwhile to explore the use of sustainable materials in construction works. These include novel building and construction materials reclaimed from waste generated from building and construction related activities and other 'fit for purpose' materials. However for such materials, the challenges are daunting. There are no building or design codes governing their usage nor are there schemes or quality standards to ensure consistency in the quality of products produced from the upstream waste generators all the way to the downstream end users in the construction supply chain. Furthermore there are limited research studies on the use of alternative materials for building projects, or project references as a basis for engineers to specify these materials for use in projects. In the area of research and development not only are the players in the supply chain limited in resources, they have neither the incentive to

fund research and explore other sources of materials nor the impetus for using alternative materials or trying out new technologies [1].

The other challenge for these 'specialised' materials supply chains is the lack of collaboration among these players. Due to broken links within the supply chain, industry players have little or no knowledge of the suppliers of these materials, the potential demand for them and how such materials could be applied. There is also no proper system or channel where materials usage could be optimised. This results in low efficiency in the use of resources, low recycling rates and lots of wastage. Waste generated upstream, which could be potential raw materials for the players downstream, are regrettably disposed off. This lack of integration or coordination between players often resulted in insufficient raw materials for recycling, uncertainty in supply and production, thereby causing delays to projects. These factors ultimately drive up material and project costs, making sustainable construction materials even less attractive to potential customers.

One such material in particular is concrete waste, which is generated from the demolition of concrete structures. Concrete recycling is gaining recognition as a green practice worldwide. It protects the environment by eliminating the need for disposal and the readily available concrete waste could be broken down relatively easily and processed into recycled concrete aggregates (RCA). Nevertheless within the supply chain, they are not directly passed down to the construction and demolition (C&D) waste recyclers or utilised in the most efficient way.

It was observed that although the C&D waste recycling in Singapore had been established for the last few years, few members of the industry were aware of it. In addition, RCA were viewed as inferior to natural aggregates and were only used for non-structural and low value applications- as backfill or hardcore material or as sub-base material for roadworks and construction of drains and road kerbs. The rest of the concrete waste that is not utilised will be disposed off at the landfill.

The reasons for the above are due to the following:

- Waste recycling is a very small segment in the construction industry; it is often neglected and disconnected from the rest of the mainstream industry players

- Lack of awareness in the industry
- Absence of proper quality control system in the production of RCA
- Absence of relevant design codes or user specifications with respect to RCA
- Absence of established and verifiable procedures
- Uncertainty in the supply of RCA

To address these issues and for the well-being of the built environment and the development of the sustainable construction materials supply chain, BCA adopted an integrated waste-to-resource approach to recycle concrete aggregates for use in new building developments.

INITIATIVES & MEASURES

The concept of the supply chain management is "integration" for the mutual benefit of enterprises, from the industry players extracting the basic raw materials to the final customers using the materials in the supply chain [2]. This systems approach to construction management involves upstream and downstream linkages in the various processes and activities that generate value in the form of products and services [3].

With this in mind, BCA coordinated with the various key industry players in the construction supply chain (shown in Figure 1) - namely the demolition contractors, C&D waste recyclers (RCA suppliers), ready mixed concrete (RMC) suppliers, building contractors and developers- to increase the supply of building materials by maximising resource recovery of concrete waste and to drive demand by increasing the usage of RCA.

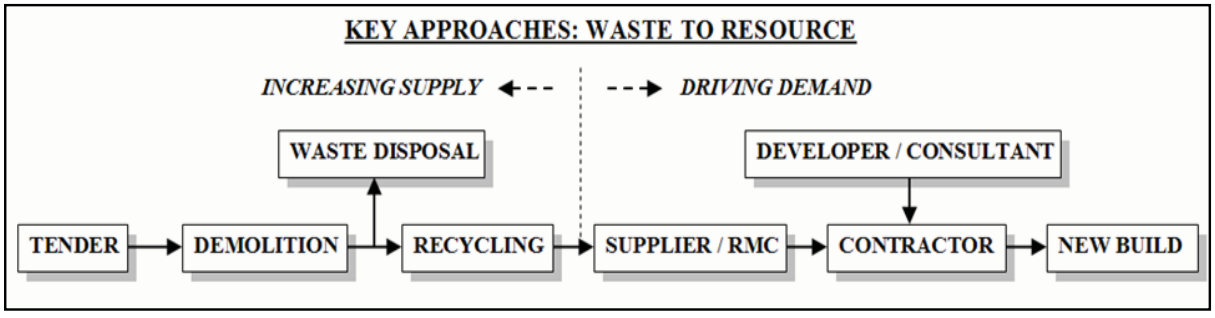

Figure 1. Waste-to-Resource Approach to maximise recycling and use of RCA

Increasing Supply and Addressing Quality Issues

The key to increasing the supply of recycled concrete aggregates (RCA) is to maximise recovery rates of concrete waste. Therefore the strategy is to formulate controls upstream so that the amount and quality of material passed downstream would improve. For this reason, BCA partnered with the relevant industry players in the supply chain to develop the demolition protocol and quality protocol.

The demolition protocol was targeted at the demolition contractors and it comprises three components- pre-demolition audit, sequential demolition and site waste management. The protocol helps demolition contractors to better plan their demolition procedures so as to maximise recovery of concrete waste for beneficial reuse/recycling. Whereas in most cases a building structure is taken down in the fastest, most economical and convenient way, resulting in difficulty of sorting out the various demolition wastes later on, this protocol facilitates the recovery and segregation of concrete from the rest of the building materials by identifying the concrete elements to be taken down very early during the demolition process. This minimises the level of 'contamination' of the concrete debris during sorting and significantly improves the quality of recovered concrete waste when they are delivered off-site to the C&D waste recyclers for RCA processing.

The quality protocol was targeted at the receivers' end- the RCA suppliers and the RMC suppliers that produce concrete incorporating RCA. BCA worked with the Waste Management and Recycling Association of Singapore (WMRAS) to develop the Accreditation Scheme for Recycled Aggregates Suppliers [4], and the Singapore Accreditation Council (SAC) to accredit RMC plants meeting certain performance criteria. Both schemes are part of BCA's efforts to promote greater self-regulation by the industry. The schemes aim to improve the quality and consistency of RCA and concrete produced, by establishing an assessment framework for the materials supply chain and by adopting relevant testing standards. The newly developed European Standards (EN), which are performance-based codes, were thus adopted for the schemes. They paved the way for the use of RCA and concrete incorporating RCA or other industrial by-products (such concrete is also termed 'green concrete').

The other benefit of these schemes is that they provide recognition to the plants committed to quality, consistency and safety of the production plant and products, thereby enhancing their image and marketability.

Driving Demand and Championing Usage

To drive the adoption and increase the demand of RCA and green concrete, BCA adopted a multi-pronged approach targeted at the major building contractors, consultants and developers.

These initiatives include a reward scheme to recognise the efforts of developers who specify the use of these materials in their building projects for environmental reasons. Points are awarded for the use of such materials in BCA's green-building rating system, the Green Mark scheme. At the same time to further drive sustainable construction initiatives and increase the take-up rates of these materials, BCA is working on a capability development fund to expand, strengthen and develop the capabilities of these players in the supply chain. The funding can be used to support technology and plant upgrading, education and training to build up knowledge and competencies, development of quality management systems and pilot trials etc.

In addition BCA collaborates with various government agencies, tertiary institutes and players in the construction supply chain to champion the use of RCA and green concrete in buildings to demonstrate the feasibility and performance of using sustainable construction materials. An excellent example is a recently completed 3-storey commercial building (Tampines Concourse), which innovatively made use of various mixes of industrial by-products in concrete such as washed copper slag, ground granulated blastfurnace slag and RCA for structural and non-structural applications. Another commercial building (Samwoh Building), slated as a showcase at the upcoming International Green Building Conference to be held in October 2009 Singapore, uses percentages of RCA beyond code limits for structural concrete. This building will be instrumented and monitored for its performance compared to regular concrete. These pilot projects testify that as long as appropriate measures and

technical considerations are in place, RCA and green concrete are just as sound as conventional building materials. To further build up the industry, knowledge gained in the process will be shared with the industry players through platforms such as conferences and seminars organised by BCA.

Due to the coordinated and integrated efforts of all the stakeholders in the construction supply chain, it was observed that more and more building contractors, consultants and developers are beginning to specify and adopt the use of such sustainable construction materials for their building projects. With the increased demand and supply of these materials, the reduction of material and production costs would ultimately translate into lower and competitive project costs.

From the systems approach perspective, what was noteworthy was that an integrated effort to recycle potential building materials resulted in a higher quantity of concrete waste being contained and used back for building works within the supply chain (refer to Figure 2). Material wastage due to poor resource allocation and low efficient usage of resources also decreased significantly.

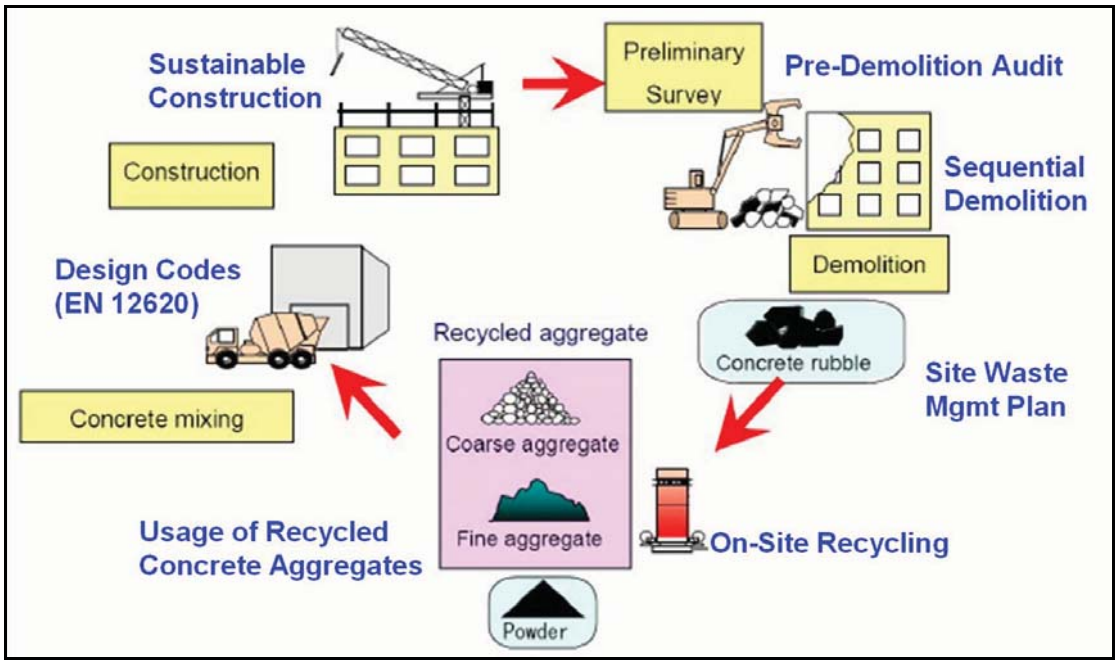

Figure 2. Closed Loop Concrete Recycling System

FUTURE DEVELOPMENTS

In literature, many supply chain methods have been proposed but successful cases are few and far between for the construction industry. While a systems approach to sustainable construction resolves fragmentation and brings the best out of the players within the construction supply chain, more studies are still needed before Singapore can successfully develop a feasible supply chain management system for the local industry. This is due to the complex nature of the construction industry, which makes a truly integrated supply chain system problematic and difficult to achieve. Many factors such as the number of supply chain partners to be involved, environmental and procurement related factors, logistics, use of sustainable materials etc, have to be carefully studied before BCA recommends for industry-wide implementation.

BCA will also continue to research into other novel waste materials generated from industrial activities and find applications for their usage by adopting a similar integrated waste-to-resource approach. Other construction technologies in the process of R&D include the "design for deconstruction" approach to building construction. Accordingly, such systems could maximise materials conservation by adopting a lifecycle management approach and by creating adaptable buildings to optimise the use of building materials.

CONCLUSION

It can be shown that the supply chain management system, when applied appropriately to sustainable construction materials, benefits the whole construction industry. With continuous improvements made within the construction supply chain and more collaboration between the industry players, resource allocation and efficiency can improve significantly, thereby optimising the use of natural materials and minimising waste through the use of recycled materials. This is indeed something worth exploring especially for a small country like Singapore with no natural resources.

In the case of novel materials recycled from waste streams that still require much research and pilot trials, an integrated systems approach to convert waste to resource is useful to address issues like quality, material applications, user confidence, costs, demand and supply, and capability development of the whole supply chain. Once such issues are resolved, these materials would gradually find their niche in the mainstream construction materials supply chain and become acceptable substitutes to natural resources.

Lastly, with sustained and increased supply and demand of usable recycled materials for building and construction applications, material costs and consequently project costs would also lower. The use of alternative materials as substitutes to natural resources then becomes a viable and environmental-friendly option for the construction industry.

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