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Original Paper

The Case for Sustainable Concrete Waste Management in Qatar

Soud Khalifa Al-Thani[1*] & Sungho Park[1]

[1] ASTAD Engineering Consultancy and Project Management, Doha, Qatar

[*] Soud Khalifa Al-Thani, ASTAD Engineering Consultancy and Project Management, Doha, Qatar

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Abstract

The construction industry is a major generator of waste. There are many challenges associated with implementing sustainable methods to manage construction waste. While the construction industry in the State of Qatar has been adopting plenty of progressive practices, waste management, especially of concrete waste, has not advanced notably. In addition to the limited supply of limestone suitable for use as natural aggregate for concrete production in Qatar, the ability to recycle and reuse concrete waste is critical to reducing environmental impacts to meet national, regional and global environmental goals. Therefore, this research aims to identify the current status of concrete waste management practices in construction projects in Qatar exemplified by a local case-study project. Concrete waste was particularly monitored over the span of the construction stage of a large research and development facility in Qatar, benchmarking trends and practices on a certified "green" building. In response, this study addresses key challenges to concrete waste recycling and reuse to then recommend opportunities of advancements in local concrete waste management and reuse.

Keywords

concrete, waste management, construction, Qatar, demolition

1. Introduction

Generation of solid waste is a pressing problem worldwide and one that requires management, prioritizing first and foremost environmental sustainability. Construction waste refers to excess [illegible] rks or used in temporary, construction-site activities to be later disposed (Lu, Chen, Peng, & Shen, 2015). This waste includes a wide range of materials by/produced due to construction, renovation, demolition of building and/or infrastructure structures (Wu, Yu, & Shen, 2017). Construction and demolition waste generated by main activities of construction projects are among top contributors of overall waste worldwide (Lu & Yuan, 2011). The construction industry generates approximately 35% of total solid waste (Llatas,

2011) and 10%-30% of land filled waste (Begum, Siwar, Pereira, & Jaafar, 2009). Countries like Spain, the United Kingdom, Australia, Japan, Italy, the Netherlands, and Finland are among the top construction-waste-generating countries (Poon, Yu, Wong, & Yip, 2013). Disposal of waste to landfills is the most detrimental to the environment relative to other waste management approaches(Yuan & Shen, 2011) as shown in Figure 1.

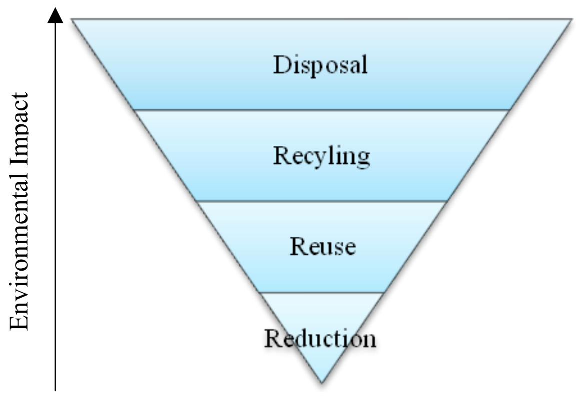

Figure 1. Environmental Impact of Construction Waste Management Approaches

As one of the world's fastest growing economies, the fast pace re/development of Qatar and the explosive population growth result in the generation of large amounts of solid wastes from all streams, e.g. municipal wastes, construction and demolition wastes, industrial wastes, etc. Figure 2 demonstrate the percentage contribution of main sectors generating solid waste from the year 2010 to 2015. Annual solid waste generation in Qatar varies around 10 million metric tons, making Qatar one of the highest per-capita waste generating countries in the world. For the large part, the solid waste is landfilled out of the metropolitan capital, Doha.

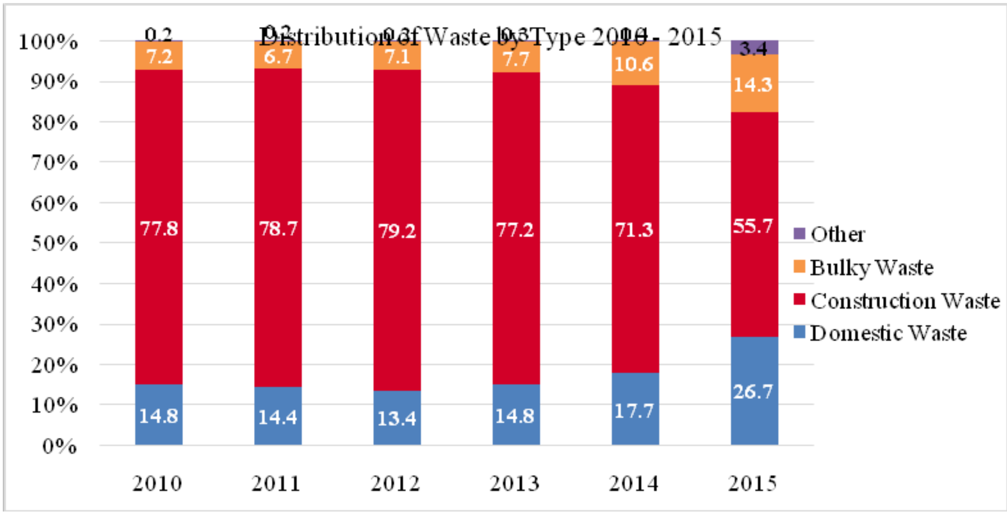

Figure 2. Total Waste Generated in Qatar by Type-Percentage (MDBS, 2015)

The country has been under international pressure to improve environmental performance, which will be paid special attention during the 2022 FIFA World Cup™ which Qatar will host. Qatar National Development Strategies target the reduction of the amount of waste produced by significantly increasing recycling and reducing landfill waste from more than 90 percent to below 65 percent (MDPS, 2018).

There are four designated locations for surplus of excavated materials in Qatar: Area 1–Simsima, Area 2–Al-Mazrouah, Area 3–Umm Al-Afaai and Area 4–Al-Karaana. Two additional areas are designated as “dump sites” for construction waste: Area 5–Rawdat Rashid and Area 6–Um Thaniyten. Of all the solid waste generated in Qatar, 75% is by construction (MDBS, 2015). Annually, 7 to 9 million metric tons of waste is sent to be buried in Rawdat Rashid landfill near the city of Mesaied (MDBS, 2015). The site has expanded rapidly in recent years to an area of about 8 km2 to accommodate to tens of million metric tons of waste every year. Figure 3 shows the vast amounts of construction waste disposed at Rawdat Rashid Landfill.

Figure 3. Concrete Waste at Rawdat Rashid Landfill (Reid, Al-Kuwari, & El-Gamil Hassan, 2016)

There have been recent efforts to lower construction waste and increase recycling and reuse (Murray Reid, Hassan, Sirin, & Taha, 2016). To date, however, waste generation (and disposal) from construction remains unregulated for the most part. These efforts most notably include Qatar Construction Specifications' (QCS) guidelines on recycled and reused materials-crushed concrete for aggregate-in Parts 8 and 9 on road works as well as Section 7 on green building (QSC-Committee, 2014).

The use of aggregates in construction in Qatar is governed by QCS (K. Hassan, Kuwari, & Reid, 2014). The 4th edition of the QCS released in 2010 had limited provisions for the use of recycled aggregates. The 5th edition of QCS published in 2014, currently in use, includes a few more provisions for the use of recycled aggregates, most importantly for unbound pavement materials, asphalt and concrete (QSC-Committee, 2014).

2. Literature Review

2.1 Incentives for Construction Waste Reduction

For a long time, researchers have worked on devising is/incentives to reduce construction waste. In one research, issuing certificates for projects using recycled aggregates was found to promote further utilization (Hendriks, 1994). Others researched viability of reward programs to minimize construction waste generation (Chen, Li, & Wong, 2002). A research from Chinaby Yuan identified 16 critical management measures that mainly establish a system of rewards and penalties for the purpose of material saving (Yuan, 2013). Udawatta et al. used qualitative and quantitative research approaches to determine ways of developing and encouraging waste management practices in nonresidential buildings (2015). The research concluded that financial incentives is one of the means ranked. Mahpour and Mortahebfurther built on incentive research and concluded that using incentives to reduce construction waste has higher ethical grounds, easy to manage and promote and more compatible with sustainable development (2018).s

Hong Kong Government initiated the “Construction Waste Disposal Charging Scheme” in 2005 to incentivize and promote reusing and recycling of construction waste (Poon et al., 2013). This program was initiated when the government came to the realization that noninert wastes being land filled in Hong Kong’s landfills were going to fill all of them within a few years (Lu & Yuan, 2011).

2.2 Concrete Waste Recycling to Aggregates

Prior to reuse, concrete waste must be crushed. Almost all of the world’s production of crushed concrete is used for applications such as roadand pavement filler materials (Tošić, Marinković, Dašić, & Stanić, 2015). When the large coarse particles of crushed concrete separated using methods such as two-stage crushing, the crushed concrete is considered an alternative aggregate, referred to as Recycled Concrete Aggregate (RCA) and the remaining fine concrete is conventionally referred to as Fine Recycled Concrete Aggregate (FRCA) (Weil, Jeske, & Schebek, 2006). RAC is commonly used as a base material for road pavements, parking lots and driveways. Less commonly, RCA/FRCA is used as primary material to produce Recycled Aggregate Concrete (RAC) to be used, for example, as structural concrete (Xiao, Ma, & Ding, 2016). In this case RCA/FRCA used for RAC has to be obtained by recycling clean concrete waste where content of other building waste is very low (Dhir et al., 2019).

The use of RCA in place of Natural Aggregate (NA) has been growing for the last few years. This is mainly due to the need for recycling/reusing the concrete waste from the ever-increasing construction and demolition waste streams. The use of crushed concrete also comes as an alternative to the scarce NA that is sourced from distant locations in many cases (Marinković, Radonjanin, Malešev, & Ignjatović, 2010). Since Qatar’s land is almost exclusively limestone deposits and formations, local limestone aggregates are limited in use by construction due to their unfavorable water absorption and abrasion quality. Imported limestone and/or gabbro aggregates are widely used for construction activities in Qatar (Al-Ansary & Iyengar, 2013).

There are several studies that compare the suitability of RAC in comparison to NA concrete considering one or several dimensions, most importantly: material suitability for use, environmental impact, financial feasibility and, in some studies, social impact (Katare, Madurwar, & Raut, 2020).

With a set of multi-criteria, Tošić conducted a comparison between NA concrete and RAC (Tošić et al., 2015). The criteria involved technical, economic and environmental aspects. This is a multifaceted research in that it compares and contrasts two aggregate alternatives across multiple disciplines. The research, however, overlooked probable mass production issues.

Weil et al. conducted research on volumetric flows of materials and wastes to assess viability of closed-loop recycling of concrete to produce a type of aggregate (2006). With a similar approach, Hiete et al. discussed a model to match supply of concrete waste from construction and demolition with the demand of recycled concrete to produce aggregate (2011). Models on balancing material flows and market dynamics have been researched and developed by numerous researchers. These studies most notably include: s

- evaluating recycling versus disposal of construction and demolition waste (Marzouk & Azab, 2014),
- weighing savings to costs for various construction and demolition waste management alternatives (Zhao, Leeftink, & Rotter, 2010), and
- incentivizing reuse and discouraging disposal to landfills by imposing landfill tariffs/charges on construction and demolition waste (Corinaldesi, Moriconi, & Naik, 2010).

These studies have evaluated material streams and the possibility to balance the construction and demolition waste (and/or activities) with the either disposal or recycling/reuse. Only a few researchers have examined structural use of recycled concrete waste including Marinkovic and Dosho (Marinković et al., 2010) (Dosho, 2007).

Marinkovic et al. (2010) and Knoeri et al. (2013) conducted a comparative environmental assessment on the use of RAC compared to NA concrete. Estanqueiro (2012) conducted a life cycle assessment of the use of RCA and NA in concrete. The research highlights that use of RCA to replace NA in concrete has an environmental implication to consider. The research suggests that more atmospheric CO2 would be absorbed by concrete produced with RCA—incrushed form—over its life cycle, in comparison to NA concrete (Corinaldesi et al., 2010). This is because the surface area of exposure in RCA and the total carbonation process taking place during the concrete life cycle is extended (Collins, 2010, 2013; Lagerblad, 2005). This incremental environmental benefit using RAC has also been studied by Collins (2013). These studies are examples of insights into one advantage with the use of RCA and RAC, but the research body of work analyzing the replacement of NA by RCA needs more research work.

Collins also evaluated financial feasibility of using RAC in ready-mix concrete plants (2013). The study covers all ready-mix concrete production operations integrating RAC but is constricted to financial practicality. Generally, there have been studies delineating the factors concerning economic recycling feasibility of construction and demolition waste (Wijayasundara, Mendis, & Ngo, 2017) as well as conducting overall feasibility analysis of concrete recycling (Coelho & De Brito, 2013). To compare concrete waste reduction to recycling, Tam assessed economics of recycling against landfilling. The study concludes that recycling of construction waste is adds economic benefits to the concrete industry (Tam, 2008). And for use, economic/market-based instruments promoting RCAoverNA were studied and presented by Duran et al. (2006). These studies have covered the financial feasibility of RAC/RCA or the enactment of policies that support the use of RCA in place of NA which are good starting grounds for wide implementation of concrete recycling. For the wide consequences on the construction industry, few studies explore financial implications of stricter concrete waste reduction measures.

3. Project Case Study

3.1 Project Background

The project is a research and development building located in Doha, Qatar. The contract of the project was design-build to fast-track the construction state-of-the-art facility for multiple tenant organizations. Gold-level certification of the US Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) was pursued and successfully obtained by the project developer under the Core and Shell (CS) category of 2009 guidelines. Construction stage took 28 months to complete.

3.2 Waste Management Specifications

The project had a dedicated Construction Waste Management Plan (CWMP) purposed to provide specific guidelines and requirements for the contractor and sub-contractors on the project. In addition to CWMP, the project's Health, Safety, Security and Environmental Plan (HSSEP) and the Construction Environmental Management Plan (CEMP) contained a few aspects of relevance to waste management/handling on the construction site but do not require any actions reduce, recycle or reuse waste.

3.3 Concrete Waste

Regulated by the CWMP, the Contractor was required to manage generated concrete waste by:

- Designating a barricaded area on or adjacent to the construction site for concrete waste.
- Breaking up large concrete waste parts in the barricaded area and break materials onsite for use only as aggregates if it was not possible to use them in their previous form
- Transferring concrete waste materials via subcontracted specialized environmental services provider to recycling and/or disposal facilities.

CWMP and waste management guidelines under LEED Certification define only handling, segregation and transportation of waste to final destination(s) with minimal scoring on done recycling and reuse. Monitoring final stage of waste end of life is not part of the LEED scoring system.

On this project, the ratio of concrete to non-concrete waste was 6:1by weight for the total construction span of over two years. Concrete waste throughout construction totaled 4,370 tons with a monthly high reaching 551 tons during the building foundation works, two months into construction phase. Non-concrete waste totaled 727.5 tons and included materials like recyclable and unrecyclable paper, food, wood, gypsum and recyclable and unrecyclable plastic.

Expectedly, generated concrete waste was at its highest as construction activities commenced onsite. Significant decrease in overall generated amounts of concrete as construction comes to a closure by nearly 140 tons (5 tons per month) on average. The amount of waste could have potentially multiplied if there were demolition activities preceding construction. Waste from construction and demolition are mostly conflated and aggregated in academic research and practice.

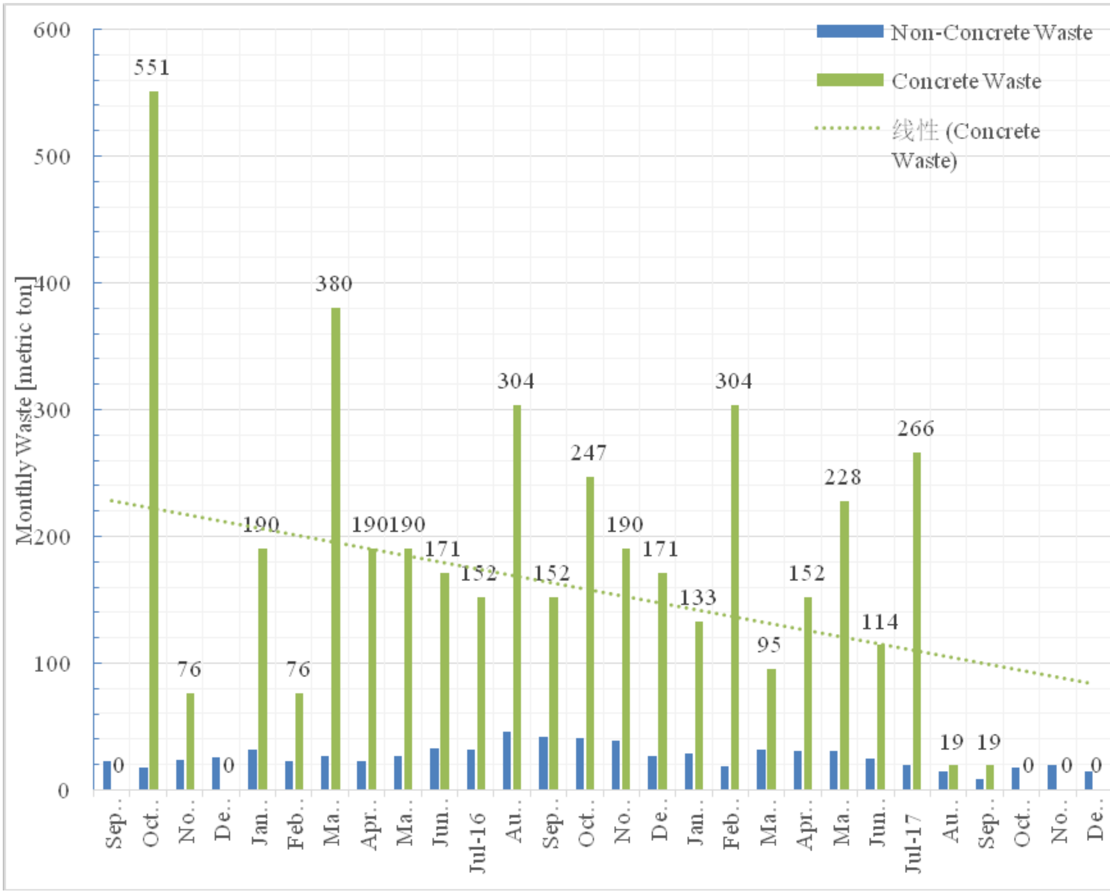

Figure 4. Concrete v. Non-Concrete Waste Generated on a Case-Study Project in Qatar

4. Issues and Challenges

- The base waste reduction requirements of LEED, a widely used green building certification system, are not stringent in that they do not dictate any aspects of recycling and/or reuse of waste materials.
- LEED green building certification system excludes several waste materials, mainly excavated soil and land-clearing debris. They do not contribute to the requirements for the LEED accreditation and cannot be included in the diversion from landfill statistics. Excavation soil typically include soil and debris from land clearing and leveling, trench excavation, concrete slab preparation. However, this opens the door for non-soil materials, including concrete, to be excluded from consideration.
- Absence of experience and good practices of waste segregation and sorting. Only one concrete waste recycling facility available in Qatar at Rawdat Rashid Landfill with modest capacity.
- Lack of segregation at source and destination increases costs of producing recycled aggregates due to the frequent damage caused to equipment by metals and non-concrete materials.
- Lack of data transparency on aggregate use during construction and after demolition on both public and private project.

- It is unconventional to include in the constructors' scope of work monitoring whether or not diverted waste was recycled or disposed after waste is received by environmental/waste management subcontractors.
- Despite the established knowledge about the use of RCA and RAC(K. E. G. Hassan, Reid, & Al-Kuwari, 2016), structural uses of RAC is almost completely absent in Qatar.
- Fortunately, waste generated onsite by non-construction-related activities is included in CWMP and contribute to the LEED accreditation. This typically requires source segregation of onsite office waste. Source segregation remains an unpopular practice in Qatar since recycling is practiced in Qatar in very limited circles.
- Throughout the construction industry, construction and demolition wastes are indistinguishable in most instances, as demolition is considered a preparatory stage for construction activities. For the case of this study, only construction waste was accounted.
- Aggregate recycling contracts in Qatar have always been awarded on commercial basis without thorough technical or environmental evaluation. In addition to attracting incompetent contractors, this practice perpetuates economic unviability of recycling and reuse of concrete waste.
- Appointment of specialist subcontractors to be responsible for waste management is one factor that leads to the imposition of higher royalties on locally recycled aggregates compared to primary aggregates, even if not locally sourced.
- QCS neglects the use of recycled aggregates for many applications.
- Municipalities easily approves permits to produce aggregates from excavated limestone.
- Outdated market perception in Qatar that recycled aggregates are inferior in quality and hence should be cheaper than natural aggregates propagates financial infeasibility of concrete recycling.
- Resistance from most local consultants and designers to approve RCA for use on projects not keeping up with mechanical and structural properties
- Short duration of aggregate recycling contract resulting in high depreciation cost.

5. Recommendations

- QCS regulates recycled content allowance for road filler materials, while RCA could potentially have wider range of uses such as in hollow blocks, pipe bedding, cable surrounds, soak-away surrounds and RAC.
- Receptibility of local markets to RCA will need to be studied and estimated to match it with reuse and recycling capacity.
- Research and development need to expand on technical and economic approaches to recycling concrete waste for the purpose of producing RAC for structural concrete applications.
- Qatar have the faculties to conserve resources by recycling concrete. Qatar Primary Materials Company and the Public Works Authority can be the main market drivers for the production and use of RCA.

- When deconstruction and selective demolition methods that aim to reduce and recycle concrete was are used, more employment and economic activities will be subsequently created for the newly increased business opportunities.
- Allow for recycling activities of existing construction and demolition waste at Rawdat Rashid to ameliorate environmental impact of the growing landfill and conserve the available space.
- Ease or wave tariffs and royalties on recycled aggregates and increase selling price of natural aggregate sourced from virgin materials. This can also help offset the environmental impact associated with the excessive extraction and consumption of local limestone.
- Amend QCS to broaden the scope of RCA applications.
- Incentivize developers, designers and contractors to use RCA/RAC in new projects possibly by a scorecard with added points for additional used tonnage of recycled aggregates. Financial penalties to be imposed for projects noncompliant with a minimum, predetermined score.

6. Conclusion

The recycling and reuse of construction waste, especially concrete, can be effectively expanded to produce primary materials for construction as well as aggregates for laying foundation of infrastructure as well as building projects in Qatar. A top-down approach that begins with the political will to use resources more efficiently and recycle construction waste, particularly concrete waste, can help grow existing efforts.

This research aims to baseline status of concrete waste management in Qatar and identify opportunities for improvement. Due to scarcity of data, expansive growth of construction and abundance of resource, there has been little attention paid to efficiency of resource and waste management.

7. Research Limitations

The findings of this review are based on literature review of research from across the world and one project case study from Qatar. Issues and challenges as well as corresponding recommendations here above are not exhaustive.

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