CONSTRUCTION AND DEMOLITION WASTE RECYCLING: THE CASE OF CONSTRUCTION WASTE MANAGEMENT (COWAM) PROJECT

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ABSTRACT

Construction waste in general consists of both waste generated by construction as well as demolition. Disposal of demolition waste is becoming a growing problem which became evident after the Indian Ocean Tsunami in 2004, particularly in Sri Lanka. Management of these wastes came into picture with the establishment of a C&D waste recycling plant by the Construction Waste Management (COWAM) Project. With the development of construction industry, the question arises whether COWAM plant alone is capable of managing such waste. Thus, this paper presents recommendations to further improve the COWAM plant by expanding the same into other local areas. COWAM plant was selected as a single case study and data were gathered through semi-structured interviews. It revealed lack of funds to establish recycling plants and infrastructure and unavailability of a proper C&D waste management policy in Sri Lanka as major problems. Taking contracts to demolish buildings and increasing the number of productions are the most important recommendations to improve the COWAM plant. Further, allocation of requisite budget for infrastructure and public awareness is recommended to enhance the COWAM concept in Sri Lanka.

Keywords: *Construction & Demolition Waste; COWAM Plant; Waste Management; Waste Recycling.*

1. INTRODUCTION

When considering construction and demolition (C&D) waste, generally it is defined as solid waste that arises from construction, renovation and demolition activities (Lu *et al.*, 2011). Hiete *et al.* (2011) added that C&D waste also includes by-products generated during reconstruction activities of structures such as buildings, roads and bridges. With reference to those major activities, different authors have classified C&D wastes into categories associated with the stages of construction projects such as contracting, design, procurement, transportation, material handling, on-site management and operations, and residuals or demolitions (Kulatunga *et al.*, 2006; Osmani *et al.*, 2008). Among them, when considering the amount, demolition waste takes the first place since it removes a whole structure. Thus, disposal of demolition waste is becoming a rising problem around the world and similarly in Sri Lanka (Senaratne and Wijesiri, 2008 cited Nagapan *et al.*, 2012).

Further, this became noticeable when Sri Lanka suffered from the Indian Ocean Tsunami in 2004, when disposing huge amounts of generated demolition waste became a major issue (Karunasena *et al.*, 2012; Interim Report of COWAM Project: Vision for 2018, 2008). Therefore, with the crisis at the aftermath of the Tsunami 2004, finding a method for sustainably managing C&D waste become critical in Galle, which was a severely affected city in Sri Lanka by the Tsunami, destroying more than 15000 houses. Thus, during the period of 2005-09, the Construction and Waste Management (COWAM) project, which was funded by the European Union (EU), came into picture as the most sustainable way to deal with C&D waste generated (Karunasena *et al.*, 2012). The project consisted of a C&D recycling plant called the 'COWAM Centre' to recycle most of such wastes (Interim Report of COWAM Project: Vision for 2018, 2008). However, with the development of construction industry, as more demolition wastes are generated, the question arises whether COWAM alone is capable to manage all such waste. Thus, it creates a need to realize the ways and means of improving COWAM project for the betterment of Sri

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Lankan construction industry. Therefore, aim of this study is to explore suggestions for further improvement of COWAM plant to expand it into other local areas, through four objectives, namely, (1) reviewing current C&D waste recycling practices (2) identifying strategies and practices of recycling C&D waste materials and their reuse in COWAM project (3) determining barriers to expand COWAM plant and (4) determining probable suggestions to extend the COWAM concept into other local areas of Sri Lanka.

Accordingly, research was confined to C&D waste management strategies applied in other countries with special emphasis on current situation in Sri Lanka. COWAM plant was selected as the case of the study to reveal issues of C&D waste management, since it is the only recorded C&D waste recycling plant in Sri Lanka. Further, probable suggestions were identified through literature and expert opinion to enhance the COWAM concept into other local areas. Forthcoming section illustrates findings of literature regarding C&D waste management practices in the world with special emphasis on Sri Lanka.

2. LITERATURE REVIEW

2.1. CONSTRUCTION AND DEMOLITION WASTE RECYCLING: GLOBAL PERSPECTIVE

Construction industry is identified as not environmentally friendly, since construction activities not only consume a large amount of natural resources, materials and energy, but also generate unacceptable level of solid wastes (Yuan *et al.*, 2011; Rameezdeen, 2009). Thus, it is recognized worldwide that construction activities have an effect on environment; where nowadays, C&D waste management is an emerging discipline that has attracted extensive attention of the world (Yu *et al.*, 2012; Lu *et al.*, 2011). Waste management is identified as any technique or procedure which avoids, eliminates or reduces waste or allows reuse or recycling for benign purposes (Sustainable Construction, 1994 as cited in Tam, 2010). Although C&D waste management process can be categorized into several stages, Teo and Loosemore (2010) argued to divide the total C&D waste management process in to two as; (1) reducing wastes and (2) managing unavoidable wastes. Reduction is considered as the most effective and efficient strategy, however, it is not fitted with unavoidable waste, such as demolition waste which needs to be managed through either 'reuse', 'recycling' or 'disposal' (3Rs principle) (Tam and Tam, 2008; Teo and Loosemore, 2010). Among them, since recycling has twin benefits of material/ energy conservation and reduced disposal efforts (Sushil,1990), many countries made great efforts to increase C&D waste recycling to reduce massive amounts of waste and conserve natural aggregate resources (Hiete *et al.*, 2011). Recycling generally refers to use of undesirable outputs or wastes as input in the same process or system, or from one process/ system as input to some other process/ system as a raw material or for generation of power or by-products (Sushil,1990).

The global contribution of C&D waste to total waste generation during the last decade differed considerably among countries, from Japan (36%) and Germany (19%) to the United States (29%), Hong Kong (38%), Australia (42%), the UK (50%) and Spain (70%) (Tam, 2010; Tam*et al.*, 2007; Fischer and Werge, 2009 cited Hiete *et al.*, 2011). Further, it was about 15% in Brazil, 20-50% in Denmark and 25% in France (Yu *et al.*, 2012). Among them the majority ends up in landfills, in uncontrolled sites or in other inappropriate places around the world (Llatas, 2011). Due to this common practice, number of impacts on environment, including pollution of air, surface water and underground water, risks to public health and loss of natural resources were identified within last decades, thus disposing of construction waste in landfills is identified as both economically and environmentally costly, wasting both natural resources and valuable landfill spaces (Llatas, 2011; Rameezdeen, 2009). Meanwhile, in some countries there is considerable pressure to encourage recycling due to their own factors, such as in Taiwan due to shortage of raw materials and in Hong Kong due to limited landfill areas (Huang *et al.*, 2002; Tam and Tam, 2007 cited Hiete *et al.*, 2011). Further, as European Parliament (2008 cited Llatas, 2011) stated, the new European challenge is to achieve a minimum of 70% reuse, recycling or other material recovery by weight of C&D waste by 2020 in EU member states. Because, it is estimated that about 20 % of the total material requirement for construction industry could be met by reuse/ recycling of materials, although this percentage will vary from industry to industry (Sushil, 1990). As identified by Franklin Associates (1998 cited Llatas, 2011), one of the main barriers to achieve such objectives is that, in spite of C&D waste

having long been a worldwide priority, there is still insufficient knowledge about this waste stream. It was known that a major part of C&D waste is generally inert, and therefore, may not pose an environmental threat as great as hazardous waste or typical municipal solid waste (Wang *et al.*, 2004). This feature has precisely meant that they have not been controlled in many regions with respect to other waste streams, which has resulted in lack of data and statistics on this waste flow. In the US, for example, a recent study indicates that actual amount of C&D debris generated is unknown (Cochran and Townsend, 2010). In Europe, most data available today is extracted from a study undertaken by several European consultants for the European Commission in 1999 (Symonds, 1999 cited Llatas, 2011). In addition, in Spain the current National Plan of Construction Waste recognizes that it has not been possible to determine an exact figure for annual production of C&D waste due to lack of reliable statistics (Spanish Government-Ministry of the Environment, 2009).

2.2. CONSTRUCTION AND DEMOLITION WASTE RECYCLING: SRI LANKAN CONTEXT

After the Indian Ocean Tsunami of 2004, Sri Lanka faced issues such as high accident risks to pedestrians, traffic jams in already congested cities and obstructions to drainage systems, creating flash floods during monsoon and mosquito breeding grounds due to illegal dumping of C&D waste on vacant lands or road sides (Interim Report of COWAM Project: Vision for 2018, 2008). However, due to some factors such as arrival of many current landfills at full capacity, high costs to establish landfills with adequate environmental protection, public resistance to construction of local landfills, an increased interest in reducing demand for natural resources while creating a sustainable construction industry and hazardous materials contained, land filling is becoming less desirable in Sri Lanka (Jeffrey, 2011; Rameezdeen, 2009). Further, due to scarcity of vacant lands, collection and disposal issues, solid waste management became an environmental, social as well as political issue in Sri Lanka (Jayaratna, 1996; Anji, 2009 cited Karunasena and Amarathunga, 2010). However, as Nitivattananon and Borongan (2007) noted most Asian countries including Sri Lanka do not have specific goals or regulations designed for C&D waste management, although some countries include some sections in their solid waste management regulations and/ or related policies. Currently, existence of regional and national policies, laws, and regulations governing 3R principles (Reduce, Recycle, Reuse) for C&D waste is minimal in Asia. For instance, Nitivattananon and Borongan (2007) stated that, in Sri Lanka reuse and recycling such as door frames, cabok (laterite brick) is practiced up to some extent. In addition, Sri Lankan reuse and recycling industry is limited to demolition contracts only and no process wastes are being taken for reuse and recycling (Rameezdeen, 2009). Materials which are recycled in Sri Lanka and their reusable rates, according to a study done by Rameezdeen in 2009, is shown in Table 1.

In this case, development of COWAM Centre – for environmental education and information resource, awareness raising of construction waste, involvement and participation of citizens or Non-Governmental Organisations in the strategy building, dissemination of information to public tried to fill the gap of proper construction waste management procedure in Sri Lanka (Rameezedeen, 2009).

Table 1: Average Recovery Rates of Materials

Material	Reusable Rate After Recycling (%)
Door Frames	100
Window Frames	100
Brick	75
Cabok (Laterite brick)	95
Roof Timber	100
Asbestos Roofing Sheets	100
Zinc Alum Roofing Sheets	20
Cali cut Roof Tiles	85
Ceiling Panels	75
Rain Water Gutters	75
Rain Water Down Pipes	50

Material	Reusable Rate After Recycling (%)
Toilet Fittings	75
Ceiling Fans	25
Concrete Grills	40
Timber Stair case Handrails	50
Steel Gates	65
Stone Paving Blocks	55
Door sashes	100
Reinforcement Bars	11
Floor and Wall Tiles	5

Source: Rameezdeen (2009)

2.3. CONSTRUCTION WASTE RECYCLING PROJECT: COWAM CENTER, GALLE

Within this attempt, construction waste management is considered under the theme of Solid Waste Management (SWM) in Sri Lanka (Ogola *et al.*, 2011). As Karunasena and Amarathunga (2010) stated, basic legal framework required for solid waste management in Sri Lanka is provided under Government, Provincial Council and Local Authorities' regulations and legislations. Following the disastrous Indian Ocean Tsunami of 2004, disposing of C&D waste become a critical issue in the hard hit coastal belt of Sri Lanka (Rameezdeen, 2009). Within this background the COWAM project was initiated to manage C&D waste in Sri Lanka. The project was started as a pilot construction recycling plant (COWAM Newsletter, 2009). Started in January 2006, the project was due to end in June 2009. COWAM was funded through the EU-Asia Pro Eco II B - Post Tsunami Program and was led by the TuTech Innovations GmbH of Hamburg, Germany. The project partners in Sri Lanka were the Galle Municipal Council and University of Moratuwa (Interim Report of COWAM Project: Vision for 2018, 2008).

Basically, the idea of COWAM came up due to a wide range of environmental and economic problems in the Galle Municipality and its citizens, ranging from water pollution to dengue mosquito breeding to traffic accidents by inappropriate management of C&D waste (COWAM Newsletter, 2009). Therefore, with the experience of huge amount of C&D waste management, the COWAM project looked at most appropriate ways to deal with C&D waste within Galle Municipality (Karunasena *et al.*, 2012). Further, the COWAM center had a vision for 2018, which includes several goals such as increasing the number of recycling plants in Galle up to five (05), increasing the number of employees up to fifty (50) and the number of marketable recycled products from 10-15 (Rameezdeen, 2009). Moreover, there was an ultimate goal to make the Galle COWAM project a model for other local authorities. However, it can be observed that the idea of COWAM has not spread throughout Sri Lanka as expected at the beginning. Thus, the COWAM centre in Galle has become the only recorded C&D waste management plant in Sri Lanka.

3. RESEARCH METHODOLOGY

The aim of this study was to carry out an in depth investigation on C&D waste recycling strategies and practices in the COWAM project to recommend approaches to expand C&D waste recycling in Sri Lanka. Case study method was proved to be the most appropriate, as it provides access to real-life context of C&D waste generation, collection and handling (Yin, 2009). It provides a rich data set based on experiences and explanations of people and organisations involved. Further, it has the ability to test existing theories or concepts. Within this study, a single case study was selected namely, COWAM Center, as it is the only recorded C&D waste recycling plant in Sri Lanka. To collect data, interviews, documentation and direct observations were conducted. Altogether three interviews were conducted due to lack or personnel related to the COWAM Center Management Process. The three personnel were expertise respectively in Recycling process within the COWAM plant; Process management at COWAM Center; and Solid waste management at Galle Municipal area. Duration of these interviews varied from 30 to 45 minutes, conducted in Sinhala language, and recorded with the permission of interviewees.

Further, direct observations of COWAM plant site, recycling process and waste collection were conducted. Documentation was done using records and documents available at the plant to further verify the data collected through interviews and observations. Code-based content analysis technique was used to analyse the data using QSR. NVivo- version 7.0.281 (Copyright © 2007 QSR International Pvt Ltd.) software. In addition, cognitive mapping was used for proper data displaying, using the same computer software. Findings from the case study are discussed in the following section.

4. RESEARCH FINDINGS

Findings revealed that Sri Lanka is at a primary stage of C&D waste management approaches and there is no specific policy on C&D waste management. Thus, it is treated as a part of existing solid waste management policy. Ascertaining that, the interviewee 2 said "we have a general solid waste management policy, but not specifically for C&D waste. Therefore, there is no island wide accepted procedure to handle the C&D waste." C&D waste management signifies a new requirement in Sri Lanka with the development of construction industry and limitation of vacant lands.

Following sections discuss research findings of study on broad headings such as existing practices in C&D waste recycling in COWAM project, barriers to improving COWAM project and probable suggestions to enhance COWAM concept in Sri Lanka.

4.1. EXISTING PRACTICES IN C&D WASTE RECYCLING IN COWAM PROJECT

For recycling, only demolition wastes are considered at the COWAM plant. Although wastes are not collected according to types, mostly collected waste is concrete fragments while rubble is collected rarely. Among demolition wastes, ceramic products are not recycled at the plant due to handling difficulties of crushed output. An average amount of 1850 m^3 of demolition wastes are collected at the plant annually. C&D waste amounts taken to recycle by the COWAM plant within last six years are shown in Figure 1.

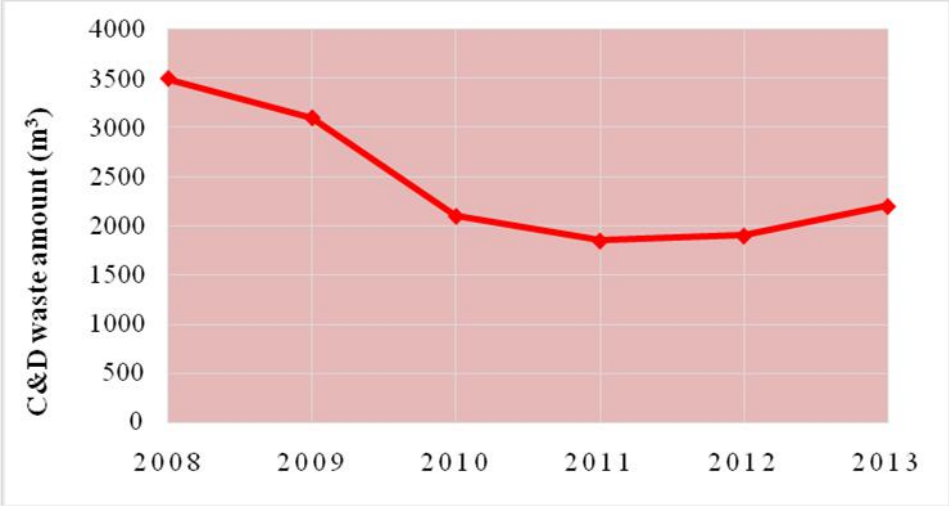

Figure 1: C&D Waste Amounts Taken to be Recycled at The COWAM Plant

Then, sorting of debris is done manually at demolition sites to separate bulk fragments and mixed waste. The wastes are transported to the plant and stored until recycled. There is adequate space for waste storing at the site of the plant. Recycling may or may not be done on the same day the waste is transported to the plant. Crushing waste materials and making entirely new items by those crushed output is the recycling process adopted within the COWAM plant. When there are larger sized waste fragments, those are needed to be made into 225x150mm size or smaller than that to feed the crushing plant as shown in Figure 2.

Figure 2: Concrete Fragments: Original Size and Hand Broken Fragments

According to direct observations, making large sized particles into smaller fragments is done manually. As the output of recycling process, it produces aggregate sizes 37.5 mm, 25mm, 19 mm, chips and sand within the plant. This output was observed as 1/3 of total waste collected. With the use of those, further they produce cement blocks and interlocking for pavements, from year 2010 onwards (See Figure 3: Productions of recycled aggregates: Interlocking and cement blocks).

Figure 3: Productions of Recycled Aggregates: Interlocking and Cement Blocks

When considering amounts of production, it was recorded that about 2000 m^3 of waste is adequate to produce 5500 cement blocks. Figure 4 illustrates the annual production of cement blocks and interlocking blocks against annual aggregate production and annual C&D waste collection.

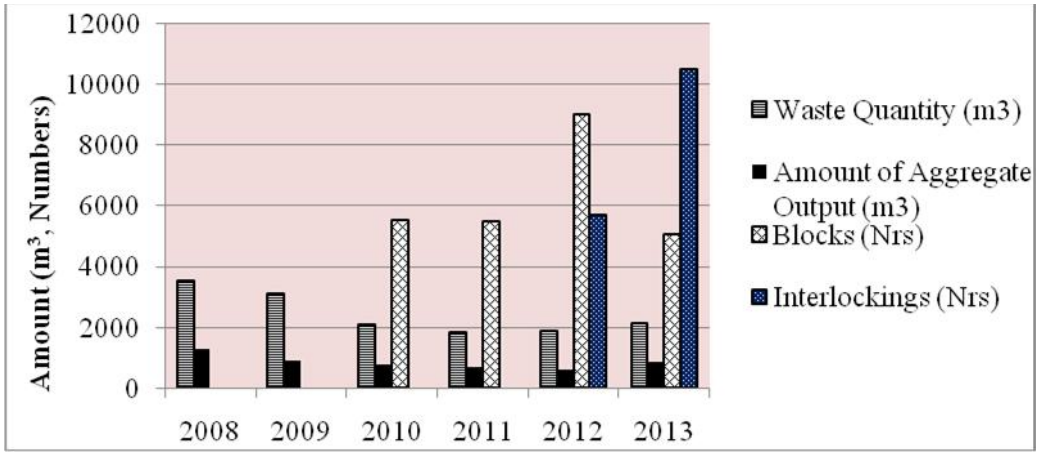

Figure 4: Annual Production against Annual Output of Aggregate and Collected Waste

The strength of those blocks have been measured through several experiments done by researchers and found that the compressive strength of blocks developed using crushed demolition waste is greater than that of conventional blocks.

4.2. PREVAILING BARRIERS TO IMPROVE THE COWAM PROJECT

Issues and barriers to improving the COWAM plant need to be better evaluated as it is more logical to consider those factors to enhance the COWAM plant to provide a better service to the country.

When considering the current situation of the COWAM plant, it was identified that there are no limitations regarding man power or skills required for the process of recycling. Meanwhile, according to empirical data, there are several issues exists such as insufficient amounts of waste received by the plant, difficulties of recycling waste in rainy days due to limited number of shelters, lack of public awareness on usability of demolition waste and lack of awareness on problems associated with illegal disposal of waste. There are further barriers related to existing practices that need be addressed through policy improvements and government support. In addition to lack of waste coming into the plant, there are some issues with financing the improvements needed at the COWAM plant. Thus, according to the interviewee 2, it is the basic reason for deviation of current situation of the plant from the objectives set in 2008. Ineffective government procedures, less government commitment, absence of a proper market identified for recycled products and absence of specific guidelines/ specifications or C&D waste management policy in Sri Lanka are further issues identified through the study.

Further, to overcome identified barriers and enhance the COWAM concept, recommendations were listed and they were discussed under two basic categories such as 'Recommendations on improvements of the project' and 'Recommendations on enhancing the concept into local area of Sri Lanka'.

4.3. RECOMMENDATIONS ON THE ENHANCEMENT OF COWAM PROJECT

In order to mitigate issues identified in existing C&D waste management procedures, several attributes can be recommended.

- ***Taking Contracts of Demolition, in Addition to Recycling***

In addition to collecting demolished debris, interviewee 1 recommended to put an advance step and take contracts of demolition of buildings. Further, the same respondent stated that "if we can take contracts of demolition of buildings, we can ensure that total amount of debris of demolished buildings come to us. In addition, we can separate debris in a proper manner and, reusable materials can be removed separately."

- ***Introducing a Movable Crusher***

Though existing procedures of recycling available at COWAM plant is sufficient for current C&D waste amount, as interviewee 1 recommended, it can be enhanced to a more effective way of recycling waste if a moveable crusher can be introduced. Interviewee 1 expressed that "if we have a moveable crusher, then we can move the crusher to a demolition site, do the crushing at the site and transport the crushed output to the COWAM plant." As he pointed out, then the wastage of demolition waste can be put to a minimum, making an effective recycling procedure.

- ***Mechanical Sorting Process***

As observed, sorting method used by the COWAM plant is simple sorting of C&D waste by hand. However, according to Tansel *et al.* (1994 cited Huang *et al.*, 2002) one critical factor that the profitability of recycling C&D wastes depends on is selected technology for recycling. Thus, a mechanical sorting process, which consists of five operational units, is another recommendation for the improvement of COWAM plant by interviewee 2. As he described, mechanical sorting includes bar screening, disk screening, magnetic separation, air classification and final manual separation, as shown in Figure 5.

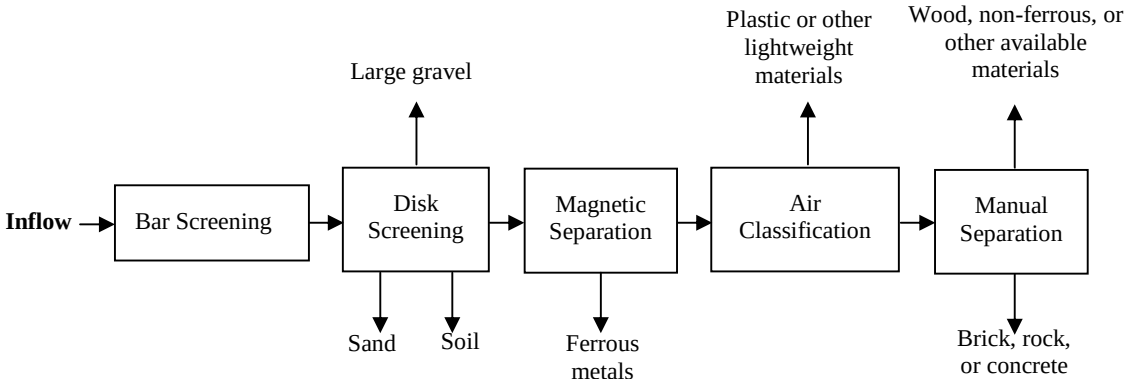

Figure 5: Mechanical Sorting Process of C&D Waste

Therefore, he further noted that if a mechanical separation method for sorting debris could be used, then the items of recycling outputs can be increased. As he mentioned, several countries in the world take advantage of such sorting processes of waste recycling, such as Taiwan, from the year 2000.

- ***Use Shadings for Storing the Collected Waste Until Recycling***

There are problems with waste recycling in rainy days. That is because in rainy days the efficiency of machine drops due to wetness of waste. Moreover, interviewee 3 indicated that in rainy seasons, the stored waste turned into a wet mixture making it difficult to be handled in a plant. Therefore, as recommended by all three interviewees, it is recommended to construct shades to cover waste piles.

- ***Increase the Number of Production Items***

According to interviewee 2 and interviewee 3, process can be expanded to produce decorative cement products such as garden furniture, concrete posts to strengthen fences, decorative load bearing concrete posts, etc. Then marketability may not be a problem, as such products have a good market demand being products that meet general requirements of people. Further, citing an example, interviewee 3 said "production at COWAM plant is also like clothing production by hand looms. If a place to sell the products of COWAM plant can be arranged, such as the "Laksala" for hand loom productions, then marketability can be achieved."

- ***Make Better Promotion of Productions Made out of Recycled Demolition Waste***

As described by interviewee 1, advertisements and other promotions can be used to inform people about products made by recycled materials.

4.4. RECOMMENDATIONS ON ENHANCING THE COWAM CONCEPT INTO LOCAL AREAS

- ***Legislation and Enforcement: Proper Waste Management Policy***

As described by interviewee 2, it is opportune to develop rules, regulations for C&D waste management and introduce a proper waste management policy in Sri Lanka, which will be helpful to spread the concept of COWAM into other local areas also. That is because, national legislation is essential for a C&D waste management system to function. It provides the legal framework to license land filling, impose a land filling levy, control handling of hazardous wastes and other activities related to C&D waste management, etc.

- ***Economic Incentives to Support the Market***

The most effective means to encourage reuse and recycling of C&D waste is to charge high taxes for land filling to discourage illegal waste disposal at landfills. Specially, this can be effective in urban and rapidly developing areas such as Colombo to reduce land filling.

- ***Information Exchange and Awareness Programs***

In order to improve the COWAM concept within other local areas, there is a need to exchange information and experiences, which takes place at workshops and seminars and through professional journals and newsletters of professional associations.

- ***Initiate Promotional Programs to Encourage Using Recycled Materials***

Government institutes such as ICTAD, SLS etc., should conduct promotional programs to encourage use of recycled materials for constructions and revise existing standards to facilitate such.

- ***Allocation of Requisite Budgets for Infrastructure***

Providing necessary capital and technologies by the government will be helpful to establish COWAM concept in other areas in the country.

5. CONCLUSIONS

This paper provides recommendations for further improvement of C&D waste recycling in Sri Lanka, based on the COWAM recycling project. Encountered main issues include limited finances available to the Galle Municipal Council to enhance this project and unavailability of proper C&D waste management policy in Sri Lanka. In order to overcome such issues, further recommendations were suggested, including; taking contracts to demolish buildings in addition to collecting debris, introduce a movable crusher to crush demolition waste at demolition sites, introducing products such as garden furniture, concrete posts to strengthen fences, decorative load bearing concrete posts etc. Allocation of requisite budget for infrastructure, which is required to implement a recycling plant and introduction of a proper C&D waste management policy were considered as recommendations to expand of the COWAM concept into other local areas.

5.1. CONTRIBUTIONS

This research unearthed a less considered side of construction industry; building demolition waste management. Although it is less considered by people involved in the construction industry, the researcher presented that there are opportunities to optimize sustainable use and management of demolition waste for an environmental friendly construction industry. Thus, the contribution of research to the construction industry can be listed as bellow.

- Construction industry generates an unacceptable level of solid waste, while consuming a large amount of natural resources, materials, and energy. In addition, most raw materials used in construction industry come from non-renewable resources. Therefore, for sustainable construction persistence, managing of waste generation must be considered.
- When considering the content of construction associated waste, demolition waste is at least double of it. Therefore, while considering construction waste management, demolition waste must be given the priority. Hence, implications of this research were mainly focused on identifying probability of managing demolition waste generation through waste recycling.
- Further, research findings revealed that recycling of demolition waste can generate entirely new products, which can be used for cost effective constructions. Therefore, improving the COWAM plant will be a vast saving of virgin materials in the country.

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