Recycling of Construction and Demolition Waste (CDW) Towards Sustainable Beneficial Outcomes

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Abstract— Population growth, industrialization and infrastructure development have continued to result in large amounts of construction and demolition waste (CDW) been dumped in landfills. The various enormous construction, demolition, remodeling, restructuring, renovation and repairs on domestic and industrial buildings as well as projects on infrastructure growth generate vast amounts of CDW considered low risk but of high volume. In South Africa and other African countries, CDW often ends up in landfills for lack of feasible recycling and reuse options. Considering the quantity of CDW insistently generated, it is expected that these wastes are converted to wealth if appreciated as useful resource for energy recovery, recycling or reuse. The need for recycling and reuse alternatives have increased in recent years with pressing concerns on the impacts of landfill disposal of CDW on the environment and human health. Irrespective of growing concerns, it is clear that landfilling will remain the main waste management disposal system for CDW in the foreseeable future. Hence, the study pinpoints the importance of recycling and reusing CDW towards beneficial outcomes. CDW can be profitably harnessed if properly sorted, crushed and sieved using the cheapest appropriate technology possible for concrete works. If well established, recycling and reuse alternatives can be efficiently implemented by incorporation into concrete technology with keen eyes for low cost housing schemes for social benefits.

Keywords Landfill, Construction and Demolition Waste, Recycling, Appropriate technology

I. Introduction

Continued developmental projects i.e., buildings, roads, dams, bridges, demolition of old structures and construction of new ones results in massive generation of CDW around the world. In developing countries such as South Africa and other African states, these activities are constantly on the rise thereby constituting a significant amount of generated solid waste often disposed in landfills for difficulties of optional handling measures. Waste from construction and demolition activities are often considered low risk to the health of inhabitants and the environment. In recent times however, the co-disposal of CDW with other hazardous elements from construction and demolition of structures with toxic chemical demanding operations have increased health concerns. South Africa generates 41,000 tons of solid waste daily as recorded by [1] which includes large amounts of CDW. South Africa will continue to depend on the landfilling system for a long time to come until economical recycling options are in full scale. These voluminous generated wastes are however, often very bulky and occupy significant dumping space; with the challenges of fast filling up waste sites, disposal land is becoming a whole new and huge problem as CDW continues to affect the aesthetics of surroundings and constitute a nuisance to the environment when openly piled. It is a close to normal experience that in large projects, heavy mountains of CDW are stacked on roads resulting in air congestion from particles and dust as well as traffic disruption and congestion [2]. For these and similar reasons, it is imperative that proper management of CDW is given a closer look such that it should be seen as a useful resource converted from waste to wealth. In South Africa where land for disposal purposes are scarce, environmental concerns are on the high and small scale businesses are clamored for; CDW recycling, reuse, reclamation and transformation should be seen as an opportunity for a greener and resourceful approach towards environmental, economic and social benefits. The conversion of waste to wealth alongside the preservation of the environment and conservation of rapidly depleting natural resources, invariably securing the health state of inhabitants is key to sustainable beneficial outcomes. As recorded by [3] increasing population, industrial and infrastructure development increases strains on already depleting natural resources used as construction materials which consequently heighten the stress on CDW disposal challenges in landfills. These challenges as explained by [4] resulting from massive concrete wastes in construction of new structures and demolition of old ones contributes to environmental and ecological issues. The recycling and reuse of waste aggregates from CDW can be harnessed to ease the pressure both on scarce resources and on waste disposal sites. Cheap and appropriate technology can be utilized in recycling CDW particularly concrete and masonry waste by sorting, crushing and sieving into recycled materials. This conversion process of waste into a useful resource can be utilized as aggregates for buildings and roads. The skepticism of the public towards recycled CDW can be relaxed by setting up producer targeted product quality and ensuring a minimum quality requirement for users. This can be achieved by initiating and adopting quality standards for recycled aggregate and concrete materials [2].

II. CHARACTERIZATION OF CDW

A. CDW Categorization

Categorizing CDW may be a complex process as it differs from place to place considering the myriad materials used in the building and construction industry across the globe. However, CDW materials may be generally categorized into a few major and minor components as shown in Table 1. Nevertheless, CDW have been further characterized by [5] into 6 categories as shown in Figure 1. The proper management of CDW has become dire in recent times as such, involves a number of systematic approach towards beneficial ends.

Table 1 Major and minor categories of CDW components

Major components	Minor components
Bricks	Panels (i.e., laminated, wooden etc)
Concrete	Pipes (i.e., plastic, iron etc)
Mortar (i.e., plasters, putties, pastes, gels, seals etc)	Tapes
Rubble	Fixtures and fittings (i.e., switches, insulators etc)
Wood (i.e., planks, plywood, logs etc)	Paints
Aggregates (i.e., coarse and fine)	Glass panes
Steel (i.e., roof sheets, railings, frames, bars etc)	Tiles

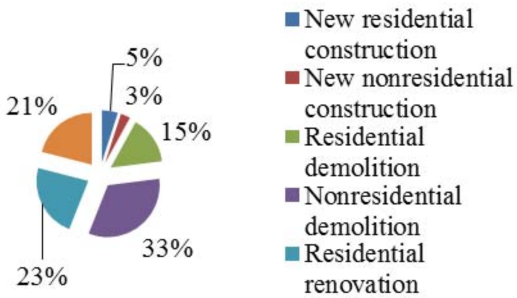

Figure 1 Characterization of CDW from building material components categorized into 6 culled from [5]

Hence, CDW management relates to appropriate storage, collection and transportation, recovery and recycling, processing, reusing and disposal of the reused product in ways with little or no consequential impacts on human and environmental health and conforms to all required standardized considerations as noted by [6]. It is also noted that due to the myriad building and construction methods as well as the diverse building materials around the globe together with different environmental protection regulations, management approaches are bound to vary from place to place.

B. CDW Recycling and Reuse Alternatives

Considering the weight and volume of CDW often generated from associated activities, its disposal poses a number of challenges; as it is mostly unsuitable to be discarded by either composting or incineration. Then again, the increasing population growth, industrialization and infrastructure developmental projects amongst other uses of land have drastically increased the cost and unavailability of land for disposal purposes as recorded by [2]. Waste transformation and reclamation or recycling and reuse have become a vital management approach requiring cheap and appropriate technology for sustainable benefits. This approach outside the pressing challenges associated with management of CDW, supports the initiation of reuse and recycling measures towards reduced pressures on depleting raw materials, reduced conveyance/transportation cost, improved profits/benefits and reduced environmental and human health impact. Furthermore, rapidly depleting natural resources of conventional aggregate has warranted the adoption of recycling and reuse alternative technology. As noted by [7] appropriate technology can help conserve natural resources by reducing excessive demand and providing greener approaches and optional construction/building materials as products of recycling. In this light, it is clear that from insistent waste generation and increasing environmental concerns, recycling of CDW materials can be harnessed within the building/construction industry with the cheapest technology possible for sustainable profitable outcomes.

III. HANDLING OF CDW

A. CDW Collection and Conveyance

The collection and conveyance of CDW debris requires certain plants and equipment depending the weight and volume been dealt with. However, CDW are often heavy and bulky especially where major construction projects are concerned. This call for CDW to be stored in skips and then skip lifters fitted with hydraulic crane system should be utilized for efficient and quick removal effects. In some cases, trailers are used and then tractors can be utilized to facilitate hastened CDW conveyance. In instances where heavy voluminous materials are to be conveyed, front-end loaders together with tipper trucks may be utilized such that loading and offloading is promptly done.

B. CDW Storage and Separation

From site visits, it was found out that CDW are best and mostly stored in piles at the generation source. As such, if littered around or idly dumped on access roads they tend to obstruct traffic leading to congestion as well as constituent nuisance to the public among other risks of environmental pollution. Proper barricades are often required to keep the waste materials in safe and orderly manner not appearing ghastly to the public. With respect to separation of CDW materials, this can be done at the generation source during construction or demolition activities by selecting and processing the materials to remove unwanted components. As stated by [2] separation at the waste generation source is considered most efficient considering time, cost and energy conservation benefits. The in-situ separation of CDW into different waste components i.e., structural building materials, road and paving materials, intact parts and site sweep-out is crucial as it facilitates the conservation of time and energy as well as aid the identification of waste materials to be transformed to useful resources. In other cases, a more specialized separation approach is needed to ensure the salvaging, reusing and recycling of certain materials such as; ceiling boards, plasters, plastics, frames, fittings and fixtures, cables, ducts, pipes, glass etc., prior to demolition such that recycled products will conform to required specifications and standards.

C. *CDW Disposal*

Apart from the density and volume of CDW which poses a disposal problem, it is mostly a non-degradable waste type as such is considered inert as no chemical or bio-chemical contamination is expected when disposed thereby, leaving no consequential impact on the environment or on human health. In recent times however, concerns are been raised with respect to the co-deposition of CDW with other chemical containing building/construction waste i.e., Chromated Copper Arsenate (CCA) treated materials, paints and other heavy chemical contaminants used in construction and demolition activities; which have been found to have consequential impacts on the environment and human health by contaminating air, soil, surface and groundwater systems. In fast developing countries like South Africa where enormous amounts of CDW are constantly generated and disposed in landfills, utmost efforts should be made to recycle and reuse these waste materials such that waste becomes transformed to wealth for sustainable social and economical benefits.

IV. 4 General Discussions on CDW

A. *Concrete as Major CDW Component*

There are concrete from structural elements of building having reinforced concrete and also mass non-reinforced concrete used in foundation construction. In construction activities, top soil, clay, sand and gravel are excavated and these materials may be reused/recycled for use as raw building materials, sub base layers in road construction, liners in landfill construction, backfills on completion of construction at the same site or ground fills in recaptured land for future development [2]. Concrete and masonry waste recycling approach involves crushing larger debris to specified particle sizes. As indicated by [2] plants and equipments for processing demolition waste differ by virtue of sizes, mobility, type of crusher and separation method. Three types of recycling plants have been identified by [8] namely; mobile, semi-mobile and fixed plants; where in the mobile plant the waste material is crushed and screened with ferrous impurities extracted by magnetic separation method. The crusher is usually transported to operation site where selected suitable non-contaminated concrete or masonry waste can be processed to meet specified standards. In the case of the semi mobile plant, contaminated components are manually separated by hand with the final product also undergoing screening with the extraction of ferrous impurities achieved by the magnetic method. It is believed that the end product from the semi-plant has higher quality than that of the mobile plant as recorded by [2]. Out of the 41,000 tons of solid waste generated in South Africa daily, a huge portion of it constitutes CDW composed of concrete and masonry materials disposed in landfills which ideally can be recycled and reused in the building industry in forms of blocks and slabs among other structural elements with less complexity. The conversion of this waste to wealth in various forms promotes sustainable beneficial outcomes by saving land used as disposal sites and easing the pressures on scarce natural resources while creating job opportunities for locals as well as creating avenues for small scale businesses to thrive. Whereas fixed plants are specially designed to execute the crushing, screening and purification processes all at ago with the products having the highest quality. However, certain factors are considered when setting up a fixed recycling plant namely: site and plant location, road and plant accessibility, land space availability, availability of weigh stage and availability storage space among other things. Figure 2a and b shows the view of a CDW management setup with crushers and skippers/containers as culled from [9].

Figure 2 (a) View of a CDW management setup as per [9]

Figure 2 (b) View of a mobile crusher and skippers/containers as per [9]

B. *CDW Applications*

Recycled CDW as coarse or fine aggregates can be utilized as bulk and backfill materials, sub base material in road and pavement construction, landfill liners, canal lining, fills in land reclamation and drainage projects as well as in the production of new concrete with less structural complexities [2]. Considering ongoing concerns on environmental protection, it must be ensured that materials in direct contact with the earth as fillers are free of contaminants to avoid risk of soil, surface and groundwater contamination. Well recycled CDW aggregates are widely incorporated as sub base layers in road and pavement construction. Demolition activities result in masonry and brick waste which when proper recycled are mixed with cement, mortar or lime to activate its properties and used as a new material. They are often used as building materials or in the construction of road and drainage layers or in mechanical soil stabilization as a result of its inert nature. Recycling of tiles and other ceramic materials undergo similar processes as masonry and brick materials and are usually mixed together to form the recycled product. In the case of metal waste, it is often generated from demolition activities and collected in forms of pipes, light sheets, wires and metal fittings, reinforcement bars in the concrete etc., which are easily separated by magnetic process and melted. Materials made of aluminium are easily recovered without contamination and are sold to recyclers. In cases where wood is recovered in good state as frames, windows, doors, beams, roofing members, partitions etc., they are easily cleaned up and reused. Nevertheless, there are instances where wood is treated with chemicals (CCA) to prevent fungi and termite attacks. In such an instance, proper disposal methods must be ensured. High quality waste wood members have high market value for reuse in flooring and furniture while lower quality wood waste can be recycled or in very common cases, burnt for energy recovery. As noted by [2] wood scrap can be mechanically shredded in-situ and sorted for metal scraps i.e., joints, screws, nails, clips etc., using magnetic separation method which can eventually be used as fuel energy source. Other applications can include its use in the manufacture of fiber, laminated and press boards. In road works, asphalt placement and scarification results in bituminous materials which when recycled in an asphalt plant by hot or cold mixing methods can be reused thereby saving cost, asphalt material, energy and constituent materials. Smaller waste materials i.e., paper, plastic etc., can be easily recovered and treated/recycled for use as emphasized by [2].

C. *Environmental Implication of CDW*

There are always significant environmental implications in any construction project observed from the extraction of raw materials, energy consumption in transportation and production processes, production of massive byproducts which could lead to consequential effects on the health state of inhabitants and the environment. As earlier noted, disposal of CDW has become a major concern present times as improper and illegal disposal practices are engaged by some building owners, waste haulers and demolition contractors avoiding transportation costs and tipping charges at waste disposal facilities. As recorded by [2] illegal disposition of CDW end up in gravel pits, water logged areas, farm land and open dumps. This practice poses a high risk of soil, surface and groundwater contamination from trace amounts of hazardous constituents present in the waste body [10]. A higher threat of environmental contamination may result from the buildup of trace amounts of hazardous constituents i.e., heavy metals, chemical and organic compounds present in substances applied to construction materials e.g., CCA treated materials or by the improper disposal of residues or bulk chemicals in the waste bodies. Ground water quality may also be degraded resulting from significantly high concentrations of generally non-toxic chemicals i.e., Na+, Cl+ NH3+ ions that may migrate to groundwater reserves from CDW generated leachate at landfills or dump sites. Thus, if such illegally practices are not checked it could attract more illegal disposal of other types of waste i.e., conventional municipal waste, industrial waste and in worst cases hazardous waste which will increase the impact to the site as well as incur more cost during future clean up processes. Open burning of demolition waste is discouraged as it poses major health concerns from air pollution as plastic, treated wood, insulation foam and painted materials among others releases toxic fumes, ash and sooth residue when burnt. In contact with water, leachate is formed from the ashes which can consequentially impact groundwater [10].

V. CONCLUSIONS

CDW will continually be disposed in landfills as the primary form of waste management in South Africa and other countries in the foreseeable future till economic recycling and reuse options are initiated. The study has therefore highlighted the significant importance of recycling CDW towards sustainable social, economic and environmental benefits. In light of this, the following conclusions were reached:

i. That CDW can be transformed from waste to wealth using very cheap appropriate technology with significantly low or no environmental impact at all.

ii. That recycling and reuse of CDW normally disposed in landfills or openly dumped will reduce the stress on presently scarce and costly land as well as the strain on already depleting natural reserves.

iii. The illegal and improper disposal of CDW can over time lead to environmental pollution particularly with respect to migrating leachate containing hazardous constituents as a result of co-deposition cases.

iv. The need for recycling and reuse of CDW is in a dire state and requires immediate action particularly for a fast growing country like South Africa as this will promote sustainable beneficial outcomes for locals, mushroom industries and businesses towards social, economic and environmental benefits.

In a nutshell, from the quantity of CDW continually generated it is only normal that these wastes are converted to useful resources in energy recovery, recycling or reutilization. Considering that the need for recycling and reuse options have increased lately over rising concerns on the impacts of landfilling of CDW on the environment and human health, a crucial paradigm shift is expected. It is however noted that, regardless of growing concerns landfilling will remain the main waste management disposal system for CDW until a drastic and feasible recycling and reuse option is adopted with particular interest in developing Africa. As such, the paper pinpointed the relevance of recycling and reusing CDW towards beneficial outcomes as this can be profitably harnessed using the cheapest appropriate technology possible.

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REFERENCES

[1] Agbenyeku E.E. & Akinseye S.A. Leachate Percolation through Failed Geomembrane of a Geo-Composite Soil Barrier, World Journal of Environmental Engineering, Vol. 3, No. 2, 52-57, 2015.

[2] Hemalatha B.R. Nagendra P. & Venkata S.B.V. Construction and Demolition Waste Recycling for Sustainable Growth and Development, Journal of Environmental Research And Development Vol. 2, No. 4, April-June 2008.

[3] Timothy G. The management and Environmental Impacts of C&D waste in Florida, University of Florida, Florida, 1998.

[4] Elisabeth S. Assessment of Two different separate techniques for Building wastes, Waste management & Research, 18, 16-24, 2000.

[5] United States Environmental Protection Agency (US EPA). "A Probabilistic Risk Assessment for Children Who Contact CCA-Treated Playsets and Decks," Draft Preliminary Report, Office of Pesticide Programs, Antimicrobials Division, November 10, 2003a.

[6] Akash R. Use of Aggregates from recycled Construction and Demolition waste in Concrete, Resources Conservation & Recycling, Elsevier, 2006.

[7] Agbenyeku E.E. & Aneke I.F. Prolonged Curing of Green Concrete from Domestically Derived Cassava Peels Ash and Laterite, International Journal of Scientific and Engineering Research. Vol 5:1: pp. 900-905, 2014.

[8] Treating Construction and Demolition, Waste Israel Environmental Bulletin, 27, 2004.

[9] Shishir B. & Singh S.K. A Sustainable Approach towards the Construction and Demolition Waste, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 2, February 2014.

[10] Agbenyeku E.E. Muzenda E. & Msibi I.M. "Zeolitic Mineral Liner as Hydraulic and Buffering Material", International Conference on Earth, Environment and Life sciences (EELS-2014) Dec. 23-24, Dubai (UAE), 2014a.