*A Dissertation on*

# *SUSTAINABLE MANAGEMENT OF CONSTRUCTION AND DEMOLITION WASTE IN INDIA*

*Submitted in partial fulfilment of the requirement for the award of degree of*

Master of Technology
(Environmental Engineering)

*By*


VARUN
(2K15/ENE/15)


*under supervision of*


DR. ANIL KUMAR HARITASH
Assistant Professor



Department of Environmental Engineering
Delhi Technological University


June 2017

# *Certificate*

*This is to certify that Mr. VARUN, M. Tech. student in the Department of Environmental Engineering has submitted a project report on "SUSTAINABLE MANAGEMENT OF CONSTRUCTION AND DEMOLITION WASTE IN INDIA" in partial fulfillment of the requirement for award of degree of Master of Technology in Environmental Engineering, during the academic year 2016-17.*

*It is a record of the student's research work prepared under my supervision and guidance.*

Dr. Anil Kumar Haritash
Assistant Professor
Department of Env. Engg.
Delhi Technological University

# *Declaration of Originality*

I hereby undertake that I am the sole author of this report. I undertake that this report neither infringes upon anyone's copyright nor violates any proprietary rights to the best of my knowledge. Any ideas, techniques, quotations, or any other material form of work of other people included in this report, published or otherwise, are fully acknowledged in accordance with the standard referencing practices.

I declare that this is the true copy of my report, including all revisions, as approved by my advisor and supervisor, and that this report has not been submitted for any other degree to any other University or Institution.

VARUN
(2K15/ENE/15)

# *Acknowledgement*

I wish to express my gratitude and deep sense of indebtedness towards my guide Dr. Anil Kumar Haritash (Assistant Professor) for his enthusiasm, support, and guidance that helped me to pursue this research work entitled "SUSTAINABLE MANAGEMENT OF CONSTRUCTION AND DEMOLITION WASTE IN INDIA". I am also very thankful to Department of Environmental Engineering, Delhi Technological university for allowing me to enroll in training of two months at IL&FS Plant Burari Delhi, that acts as a base for my dissertation.

I profusely thanks Mr. Arun Kumar Sharma (Asst. Vice President) at IL&FS waste recycling plant for his kind favour and continuous guidance that helped me to understand the basic working of recycling plant and the operations carried out there. I Specially thanks Mr. Hitesh Aggarwal (Sr. Executive), Mr. Ashwani Vats (Civil Engineer) and Mrs. Sapna Rathor (Environment Engineer) whose warm support and guidance helped me to get through.

I am also very grateful to Mrs. Shivangi Singh, (HR manager) for helping me with arrangement here in IL&FS.

Lastly I would like to thank and salute the almighty God for continuously showering his blessings that makes me to reach up to this level in career.

**Varun**

(2K15/ENE/15)

# Table of Contents

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVATIONS

| | |
|---|---|
| 4 R | Reuse, Repair, Refurbish, Recycle |
| ASTM | American Society For Testing and Materials |
| AASHTO | American Association of State Highway & Transportation Officials |
| BSB | Brick Sub Base |
| C&D | Construction and Demolition Waste |
| C2C | Cradle to Cradle |
| CE | Circular Economy |
| CPCB | Central Pollution Control Board |
| CRRI | Central Road Research Institute |
| CSE | Centre for Science and Environment |
| DDA | Delhi Development Authority |
| EPR | Extended Producers Responsibility |
| EU | European union |
| GDP | Gross Domestic Product |
| GVA | Gross Value Added |
| IEISL | IL&FS Environmental Infrastructure & Services Limited |
| IL&FS | Infrastructure Leasing & Financial Services |
| LCA | Life Cycle Assessment |
| LCT | Life Cycle Thinking |
| MCD | Municipal Corporation of Delhi |
| MoEFC | Ministry of Environment Forest & Climate Change |
| MSW | Municipal Solid Waste |
| MT | Million Tons |
| NAAQS | National Ambient Air Quality Standards |
| NCCBM | National Council for Cement & Building Material |
| NDMC | North Delhi Municipal Corporation |
| NIDM | National Institute of Disaster Management |
| PAM | Poly Acryl Amide |
| $PM_{2.5}$ | Particulate Matter of size 2.5 $\mu$ |
| $PM_{10}$ | Particulate Matter of Size 10 $\mu$ |
| PPP | Public Private Partnership |
| PPP | Polluters Pays Principle |

| | |
|---|---|
| PVC | Poly Vinyl Chloride |
| TIFAC | Technology Information, Forecasting & Assessment Council |
| TPD | Tons Per Day |
| ULB | Urban Local Bodies |

# Abstract

Construction and demolition waste marks a high percentage of the total solid waste generated globally and still is continuously rising because of the boom in housing and building industry. There is not a single definition to C&D waste as it depends on a no. of factors and differs according to the location, type of the project, type of work undertaken and on the age of structure. All these issues collectively make it complicated to find a generic solution to construction and demolition waste management problems. As per a report of world bank for the year 2012, cities across the globe generates about 1.3 million ton of solid waste per annum and by 2025 it is expected to increase to 2.2 billion ton. Out of this quantity of solid waste, waste produced from construction industry known as C&D waste contributes nearly 50% globally and which will pose significant impacts on society and environment.

More over the sustainable management of C&D waste especially in developing countries like India is discussed only on political stages and on documents because the govt. don't have the approach and framework to tackle this ever growing pile of waste and the nuisance created by it as till now the conventional treatment of construction and demolition waste is to dump them either in landfills or in the water bodies. C&D waste has tremendous potential for material recovery and if policies and regulation are framed keeping in mind the idea and innovative techniques of reuse, reduce and recycle of waste, this will mark a substantial decrease in the use of virgin building material along with saving of resources for future thus making recycling the most viable option.

The present study is carried out to understand the problem of C&D waste in India; to investigate the current practices adopted; to check for the govt. policies for C&D waste; to check the Environmental impacts, socio-economic impacts and sustainability impacts; and to discuss the business opportunities for C&D waste management.

This dissertation is based on literature review carried out, case study of IL&FS waste processing facility and legal framework in the form of "C&D waste management rules 2016.

# 1. INTRODUCTION

Now a day the whole world is focused on development in lines with the environment and its protection, called sustainable development. As it is not only the scientific document or just theories that reports about the changes in climate but also the incidents that happened worldwide, forces the nations to consider the environment in their business strategies.

When it comes to environment, resources used and their efficiency plays a crucial role after the major problem of global warming as the resources are finite and won't last forever if consumed at a rate faster than the regeneration rate. As per Ellen MacArthur foundation 2013, on one hand the fast consumption of goods demands a rapid resource extraction, on the other hand it leads to a huge amount of waste. Also, the problem of global warming will aggravate further when it comes to treat the waste material as waste material treatment is energy and resources intensive. At the same time waste in any form marks the end of a products life which ultimately ends up in landfilling, incineration, or in destruction operation.

Construction is a vital link between the infrastructure and growth of economy in any country. For shaping a society buildings, dams, roadways, airports, bridges and other constructed facilities play an important role. The construction industry on the basis of technology advancement constantly strives to build taller, longer, and complex structures. One aspect of this project, that moves ahead growing exponentially, is the generation of 500 million tons of construction and demolition wastes annually (CSE, 2013).

Construction and demolition (C&D) wastes are also a part of construction and holds the same value as schedules, estimates, hammers, or nails according to the construction industry prospective. However, expenses to be made to dispose the C&D wastes have up rised in recent years, forcing the contractors to think about the waste disposal methods and to make a choice for C&D waste either a resource, or simply a rubbish. The research in this dissertation investigates about the current plight of C&D wastes and presents a plan to address sustainable management this kind of waste.

The question that arises here is: What if the waste ceases to act as a problem rather act as a substitution for resource extraction and promoting new values? This approach has been implemented by using waste management concepts such as *"zero waste strategy", "circular economy" and "cradle to cradle"* that leads to low waste generation and effective waste management (Zero waste international alliance 2013; Ellen MacArthur foundation 2013: Braungart & McDonough 2012;)

India is a fastly developing country of Asian continent and have a tremendous need for housing especially in the urban areas like Delhi and other cities. With this, the demand for building materials also rises exponentially and since concrete is the prime building material, it increases the thrust on the excavation of virgin building material. More over in both the developing and developed countries, concrete blocks are gaining importance like in UK alone in 70 % of civil projects aggregate concrete blocks are used. Thus, it marks a high demand for concrete blocks as building material globally. The construction industry accounts directly and indirectly for nearly "40% of the material flow entering the world economy" and, in developing countries, for around "50% of the total energy consumption".

In addition to the problem discussed above, the construction industry is held responsible for exploitation of natural resources as well as the release of construction and demolition waste and pollutants into the environment. The construction industry is responsible for "12-16% of fresh water consumption"; "25% exploitation of harvested wood"; "energy consumption of 30-40%"; "virgin material extraction of 40-47%"; "contributes in 20-30% of greenhouse gas emission"; "35-40% of the total waste stream. It is also estimated that "1 kg of $CO_2$ is released per kg of cement produced "(Mora, 2007) giving an idea about the amount of $CO_2$ released worldwide by cement industry alone and so the contribution of construction industry in global warming. Also, it is a fact that "10 -15% of purchased building materials" founds its way into the waste stream before delivery. In USA, the fraction of C&D waste is nearly 40% of total MSW and out of which the major portion is of concrete and aggregates. While in the western Europe, the distribution is as follows masonry (50%), concrete (35%), wood (8%), metal (4%) and plastic (3%).

The above data is on the basis of waste generated from normal activities only excluding that from the natural disasters like earthquakes, floods, tornadoes etc which alone can generate a tremendous amount of waste. Recently the world witnessed a no. of natural disasters like earthquakes in PoK, Nepal, Afghanishan, Japan etc; avalanches; tornadoes in Florida (USA) along with man-made destruction due to terrorism, wars and structural failures.

Talking in context of India, especially the Northern India (covering the hilly areas of Uttrakhand) and the coastal areas (covering Eastern coast and Western coast) are most prone to the natural calamities like floods and landsliding and cyclones respectively. The data for the destruction of houses in the 2013 Kedarnath floods as given by state government in a report to the National Institute of Disaster Management, is shown in Table number-1 listed below. So from this report we can judge the Quantum of C&D waste generated although the data may vary from given as it is only the official report.

Table 1: Infrastructure damaged during 2013 Kedarnath floods ( NIDM, 2013)

| S.no | Type of houses | No. of houses affected |
|---|---|---|
| 1 | Fully damaged pucca house | 2119 |
| 2 | Severely damaged pucca house | 3001 |
| 3 | Partially damaged pucca house | 11759 |
| 4 | Fully damaged kuchha house | 394 |
| 5 | Severely damaged kuchha house | 360 |
| 6 | Partially damaged kuchha house | 1676 |
| 7 | Huts damaged | 471 |
| 8 | Cowsheds damaged | 361 |

It is predictable that within the next 40 to 50 years to come, C&D waste generation will significantly increase. In the European region, for example, the amount of annually generated C&D waste rose from "180 million tons in 2000 (EU commission, 2000) to 510 million tons in 2009" (WBCSD, 2009). In Japan, C&D waste increased from "25 million tons in 1990 to 71 million tons in 1995", Hong Kong's annual C&D waste generation becomes more than double in a period between 1993 and 2004. Although it is true that developing countries like India lacks reliable data on C&D waste generation but the evidence from other developing countries shows that C&D waste generation would increase due to improvement in economy and rising demand of housing to keep pace with increase in population.

The concept of closed-loop material flow management is one of the best meta-strategies of sustainable waste management that can be achieved by reusing and recycling the C&D waste. The closed-loop materials flow defined as reusing C&D waste that is generated from construction and demolition activities as a new material which in turn used for construction activities. C&D waste according to Hendriks and Pietersen, (2000) is divided into five types of waste as follows:

1. Immediate usability if in good condition: Wood and steel.
2. usability after slight processing: Wood and rubble (include masonry and concrete rubble).
3. Direct Incineration: Fabrics, wood.
4. Production of new materials (recycled): Metal, wood for pyrolysis, glass, plastics.

5. Useless materials, contaminated materials (asbestos, chemical waste) or uncontaminated non-reusable materials (like plaster, whitewash residue, mixed C&D waste).

This project deals with reuse and beneficial application of the solid waste such as rubble (masonry and concrete) after processing because this constitutes a large portion of C&D waste that has high recycling potential and is not effectively managed in India. The term reuse here means to apply recovered C&D waste in its original form without altering its shape; and recycling means to alter the original shape and size of C&D waste by physical, mechanical and/or chemical actions in order to generate a totally new material with qualities meeting the required standards and specification as for the virgin material in the construction industry.

In India, the disposal of C&D waste remains a big challenge because solid C&D waste is utilized for illegal landfilling at low lying areas or dumping in water bodies, instead of reuse or recycling. Even though in Delhi there is currently no landfill areas available for solid waste disposal but still open air dumping is practiced. Due to the increasing population and demand for housing, sites required for waste disposal will even be more limited in the future. This situation will definitely put an extra pressure on C&D waste management. The use of C&D waste as a building material can provide a good option not only to manage waste flows but also for providing an alternative source.

The present study is to done to analyze the current regulations for the management of C&D waste and to investigate for value upgrading of C&D waste. On the basis of information gathered by case study of IL&FS plant and analysis of current rules and regulations for C&D waste management, the aim of the study is to develop a sustainable waste management strategy on the basis of concepts and theories like zero waste concept, cradle to cradle, life cycle thinking and circular economy; to investigate for weak regulations on hazardous C&D waste management.

Even though it is clear from statistics point of view that certain regulations have decreased the quantities of C&D waste generated and initiatives have helped to recover waste material, C&D waste is still losing its value as recycling process is seen as the only choice of recovery. This gives a pause to additional value creation and forces to assume that the information about recovery operations that is based on value addition is not efficiently transferred.

Previous studies have shown that a large number of efforts have been made at different places especially in developed countries for recycling the C&D waste into building materials in particular the concrete products such as concrete blocks. So far, the knowledge of reusing 100%

recycled C&D aggregates (fine and coarse aggregates) as a substitute to virgin building materials is still limited in India and other developing countries. Concrete and cement companies in countries like Netherlands marks the statement that they have achieved the target of maximum substitution of natural aggregates by recycled coarse aggregates i.e 30% at present Grubel et al., (1998). But USA PW technical bulletin also reported in 2004 that information on the production of concrete using building material obtained from C&D waste is still lacking especially in regards to:

a) the economic aspect of concrete processing and recycling;

b) the influence of contaminants obtained from the demolition of the buildings;

c) the long-term feasibility of recycling ;

d) the final use of recycled fines aggregates;

e) the durability and performance of concrete made with recycled coarse aggregates

Furthermore, it is reported that on comparing the recycled and the virgin material from the economy, quality and quantity point of view, recycling of C&D waste is more attractive. Many scholars use cost as economic indicator for comparing recycled products with the virgin material. However, for achieving an improved sustainability in the construction industry, it is advocated that recycled products should not only be measured on the basis of production costs, but also on the economic, social and environmental basis.

The basic principle that needs to be achieved is to create awareness for correct handling of hazardous C&D waste, that can be regulated by intervention of authorities or by business in industry. As it should not be like the case of European countries where the hazardous C&D waste like Asbestos & PCBs are handled equally as nonhazardous material in spite of the fact that they are covered by a taxation system. Thus, there evolves a need of selective demolition called deconstruction that can separate the different type of waste in its primary stage.

The objectives and the scope of the research work are summarized below:

- To quantify the waste and to generate data for C&D waste in India;
- To gain knowledge on how C&D waste can be recycled and how to add value to recycled product;
- To develop and analyze the standards, codes, and specifications for the use of recycled building material in India;
- To promote awareness about handling of hazardous C&D waste separately from the non-hazardous.

# 2. REVIEW OF LITERATURE

## 2.1 Introduction

The Waste management is a very broad concept and conventionally it implies the process of collection from generation points, in-situ segregation or segregation at any common point and transfer to a destination for the purpose of disposing or being used of.

The quantum of waste generated depends on the type of project generating the waste material namely, residential or industrial; the type of operation such as new construction, renovation, repairing and demolition and the process during which the waste is managed is attributed to waste generation.

This chapter on C&D waste deals with the definition of waste, classification of waste, waste scenario in India, current rules and regulations adopted, and case study of IL&FS waste recycling facility. Also, different concepts to manage the waste adopted worldwide is discussed here like "*cradle to cradle*", "*circular economy*" etc.

Sustainable waste management is defined as to dispose the waste material when there are no other options, to recycle the waste material in the case of being feasible, and to reuse the material before it becomes waste.

The main objective of construction and demolition waste management is to apply these solutions in order to ascertain the sustainable management of C&D waste and resources that may be time or manpower and is based on the concept of "***not to waste the waste***".

In majority of countries, waste material is either illegally disposed in landfills or near to the water bodies due to the lack of space and guidelines. This method of disposal is not only against the law, but also impacts the environment and pose adverse effects on human health leading to environmental and socio-economic loss.

C&D waste can be separated from the waste stream and the procedure through which these materials are sorted out of the main stream is called segregation and the materials are called segregated materials. The quantum of C&D materials generated depends on a no. of factors amongst which the most important ones are "macroeconomic conditions affecting construction, societal consumption trends, and natural and anthropogenic hazards" (Napier, 2012).

Even in small scale projects a considerable amount of construction waste is produced which in most of the developed countries is under the jurisdiction of local government and municipalities. It was reported by Napier (2012) that several factors influencing the management of waste materials are: -

- Availability of site for disposal of C&D waste.
- Economic status of country or nation.
- Societal priorities
- Market availability for selling the recycled products
- Transportation options

## 2.2 History of C&D waste

C&D wastes always remains a quiet aspect of construction throughout the history the industrial development. However, it is the last century that completely brought the change in the philosophy of the construction industry regarding the C&D waste. Throughout the early 1900's i.e the period when tradition of slavery exists, there was no problem with the availability of manpower as labor rates were marginal thus the main budget of project is meant for building materials. Thus, at that time it was in tradition not to waste the material at any cost whether the contractor have to put more labour for utilizing the left-over material for any unwanted purpose. This meant that contractors could not afford to discard materials, but they could afford more labor to cut and trim leftover materials for later use. It was only after World War II, that many new technologies were introduced and it began to flourish the manufacturing process of materials from the raw product. The time required to manufacture, store, and to transport it up to long distances, starts declining and it brings the rapidity in the construction of facilities like roadways, railways, bridges and many more. This innovation in the industrial sector did two things for construction materials: first, it provided consistent quality control, and second, it paves the way for mass production. The construction cost was highly improved by this highly innovative technique of "penalization of materials such as plywood and gypsumboard" as it helped in bringing improved quality at a lower price. With this the construction industry focused its mind in saving the labour cost by placing less emphasis on material wasted. For example, at that time for wall covering plaster was the only option but later plaster use was discarded due to availability of gypsum board. The problem with Plaster was that it was batched mixed, and the material cost was typically twice the cost of the labor. However, in the mid-1990's, gypsum was abundantly available as a resource and was relatively inexpensive as compared to the labor required to install it. As the inhumane treatment and slavery tradition abolished and ceases to exist, labor costs increased and thus raising the insurance, and worker's compensation fees and providing for more friendly working condition. In response to the above improvements the emphasis of industry shifted from reducing the material wastes to promote the labour efficiency.

Many a times a choice is to be made between the consumable and non-consumable materials on a construction site. The consumables accounts for the material that have physical relevance in the construction for being used and sometimes left at the construction facility for the purpose of later use or can be returned to the supplier. The best example of leftover materials is aggregates as many a times a significant volume of aggregates is left at site and that can be returned to a supplier in lieu of compensation. Non-consumables are those materials that only aid in the construction process, but do not end up in the completed structure anymore.

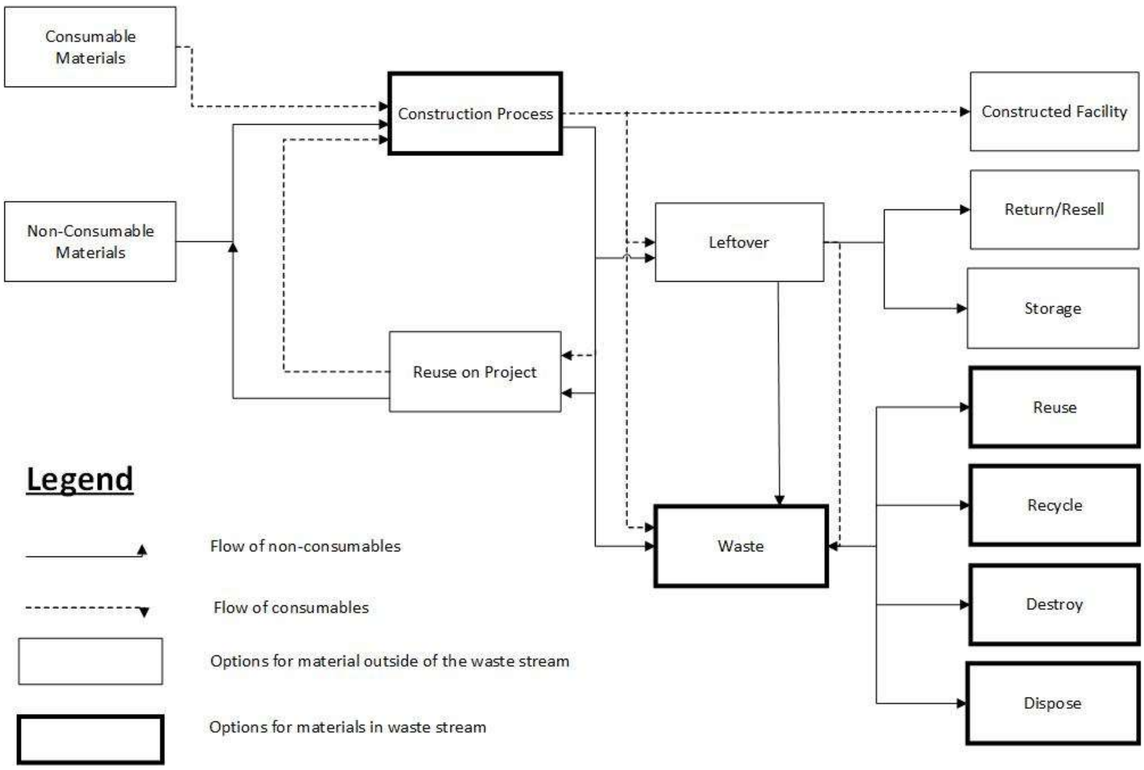


Figure 1: Flow of C&D waste in construction industry (Jarman, 1996)

## 2.3 C&D Waste Stream

According to the USA Environmental Protection Agency (EPA), C&D waste is defined as "waste that is generated from the construction, renovation, repair, and demolition of structures such as residential and commercial buildings, roads, and bridges". It mainly comprises of concrete, masonry, asphalt, and products having salvage value like metals, wood, plastics and cardboard.

The definition of construction and demolition wastes as per Tchobanoglous et al. (1977) is: "Wastes from razed buildings and other structures are classified as demolition wastes. Wastes from the construction, remodeling, and repairing of individual residences, commercial buildings, and other structures are classified as construction wastes". In most of the cases the demolition waste, a heterogeneous mixture of various building materials such as aggregate, paper, wood, metal, and glass, is contaminated with paints, insulations, wall coverings and adhesives thus raising the need for sorting prior to disposal. Activities like complete demolishing of existing structures which is done either intentionally or due to natural causes like earthquakes are the root source of C&D waste. Intentional demolition includes activities like renovation, repairing, remodeling and sometimes called as deconstruction. The type of the structure, the age of the structure, the materials used for its construction and the technique of demolition followed are among the various factors that affects the composition and the quantities of demolition wastes.

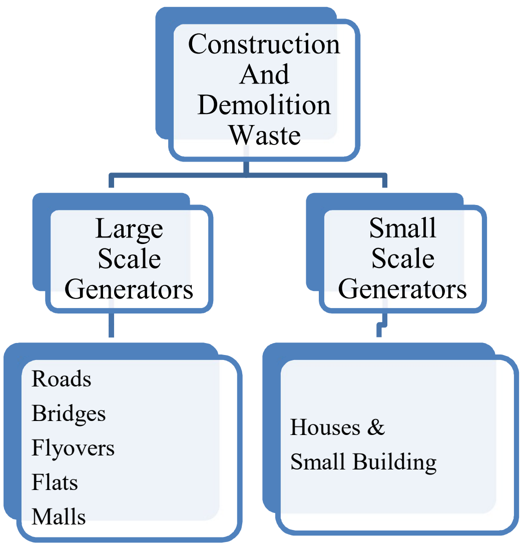


Figure 2: Sources of C&D Waste

In the past decade construction industry in India witnessed a drastic growth due to the increased investment in the real estate and building sector which is a consequence of shooting requirement of housing induced due to the rapid migration of people toward urban areas and secondly due to the flow of money in the economy of India. This pace will further accelerate as the projects regarding the smart cities are still in queue to become a reality. Generally, we have two main sources of waste generation large scale and small scale/ retail generators as shown by figure no.1. Infrastructure and real estate sector are considered as the bulk generators of waste, whereas Construction and repairs of roads, bridges, flyovers etc. are the main activities dealing with the infrastructure development sector. While Real estate sector deals with housing, institutional building, industrial buildings construction and demolition these structures covered along with unauthorized structures. Retail generators of C&D waste undertake the projects like that of small commercial enterprise and individual house building and as per the size of project the quantities of generated waste.

Gavilan and Bemold (1994) provide a system that attributes the generation of C&D wastes into six categories: “design, procurement, handling of materials, operation, residual, and other sources” as shown in the Table 2. There can be variation in the sources depending on the materials utilized in each project and due to other factors also.

Table 2: Identification of C&D Waste Sources

| **Waste** | **Cause of waste** |
|---|---|
| Design | Faulty design, sudden changes in design |
| Procurement | Error in shipping and errors in order details |
| Handling of material | Rough handling, insufficient space, and storage (on and off site) |
| Operation | Human error i.e faulty construction<br>Act of God includes earthquakes, tornadoes etc. |
| Residual | Left over material after finishing the project. |
| Other sources | |

*Gavilan and Bemold, 1994*

Many of the listed causes of waste are out of the contractor's control. Errors in design or change in the orders will lead to the wastage of material. Improper handling of the material on or off the construction site causes excess waste as materials are brought to the construction site from a considerable distance. Faulty Communication problems also acts as a source of error and in the generation of C&D wastes. Wrong details while making an Order like demanding too much or too little, or wrong material can cause wastage. Many a times, human's errors like wrong construction technique, inexperience, lack of knowledge etc act as a source of errors.

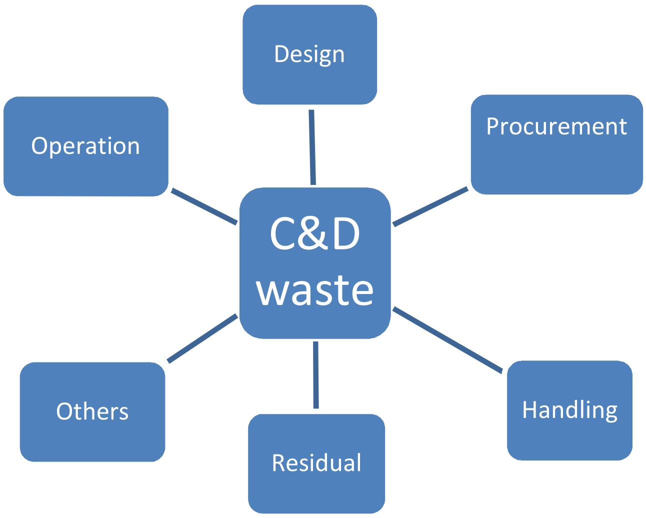


Figure 3: Sources of C&D Waste (Gavilon and Bemold 1994)

The complexity in finding a standard solution for C&D waste is the uncertainties and anomalies in its definition and it also varies according to type and location of the project executed. Based on the information gathered from literature review, it can be uttered that waste from infrastructure and road works are many a times considered as construction and demolition waste and in this also specifically the concrete and masonry waste is considered. In an attempt to give a standard definition of construction and demolition waste, the following phrases can be used in the course of this report:

"C & D waste is the waste generated either from the construction process of a building or that resulted from its demolition or including both the processes."

## 2.4 Classification of C&D waste

In the solid waste stream, the C & D waste have one of the largest representation, and poses a real threat to all countries because the composition of C&D waste is highly variable and mainly depends on a no. of factors like the techniques followed for construction and demolition, type of Structure and its intended use, location of country and status of the country and many other factors. It is this diversity in technology for construction that has led to a variability in having one standard list of C & D waste that can finds applicability to all projects in all countries.

The categorization of C&D is considered to be carried out first by Spivey (1974). He used the source based system of classification for the components of wastes in construction and demolition sites are as follows and the same is being represented in Table 3

- Construction waste (coarse sand left after sieving, gunny bags, brick bats etc)
- Demolition waste (i.e., concrete blocks, piles, brick pieces, surkhi, etc.)
- Packaging waste (i.e., paper, cardboard, plastic, etc.)
- Wood waste (timber like window panels, door frames etc)
- Concrete waste (concrete slab, surplus concrete)
- Asphalt (includes that from the damaged bituminous road)
- Garbage and sanitary waste (from the cleaning of storm sewers and municipal sewers)
- Scrap-metal waste (like that from the reinforcement bars and formwork)
- Rubber and glass (from the insulation used in the building and the glass used in the windows

Table 3: Classification of C&D waste as per Spivey (1974)

| S.No | Waste type | Components of waste |
|---|---|---|
| **1** | Construction waste | coarse sand left after sieving, gunny bags, brick bats etc |
| **2** | Demolition waste | concrete blocks, piles, brick pieces, surkhi, etc |
| **3** | Packaging waste | paper, cardboard, plastic, etc |
| **4** | Wood waste | timber like window panels, door frames etc |
| **5** | Concrete waste | concrete slab, surplus concrete |
| **6** | Asphalt | includes that from the damaged bituminous road and from their repairing |
| **7** | Garbage and sanitary waste | from the cleaning of storm sewers and municipal sewers |
| **8** | Scrap metal waste | like that from the reinforcement bars and formwork |
| **9** | Rubber and glass waste | from the insulation used in the building and the glass used in the windows |

Symonds group Ltd. (1999) also put efforts to identify the components of construction and demolition waste and it confirmed that the composition of construction and demolition waste can vary significantly from place to place and from site to site and divided it into three types of waste, originating from:

- New construction
- Deconstruction
- Demolition
- Renovation and
- Retrofitting

The renovation waste and demolition wastes have a similarity in composition up to certain limits due to the similarity in the of operation. Construction waste is generally attributed to damaged materials and surplus building material ordered prior to the start of project. Figure 4 illustrates the division of the C & D waste into demolition waste, renovation waste and construction waste across the EU countries.

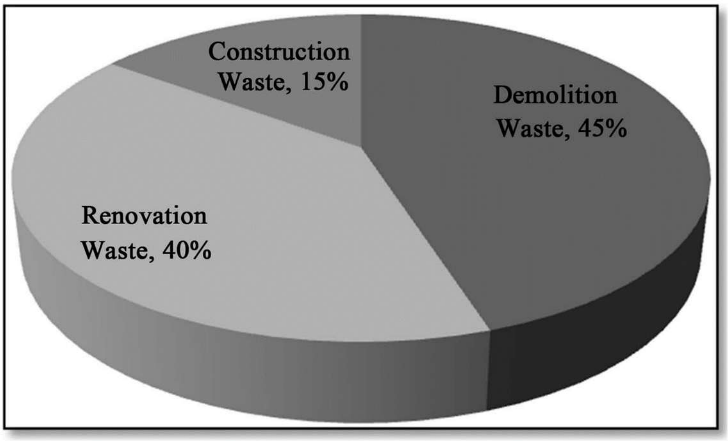


Figure 4: C & D waste in the EU countries, (Elgizawy,2016)

As per Papadopoulos et al. C&D waste is categorized according to their origin and covers a wide spectrum of materials such as:

- Excavation materials: All the materials that results from excavation work like soil, sand, gravel, rocks, clay are included in this class and they are found in almost all types of construction and infrastructure work.

- works and maintenance: it includes materials like bitumen coated aggregates, asphalt and other pavement materials such as damaged kerb stone, paver blocks, sand, gravel as well as metal and other material waste coming from road works.
- Construction debris: it consists of all kind of waste that can originate from a demoliting building such as soil, gravel, bricks, concrete, rags, or we can preferable say the mixed waste and thus making them heterogeneous in nature.
- Waste from construction site: it includes almost all materials either renewable or non-renewable like wood, plastic, paper, glass, metal etc. It results from the operation of workers on site.

A different approach for classifying construction and demolition waste is presented by Skoyles(1976) as the direct and indirect waste:

- Direct waste involves the material which is completely lost as the waste and which needs to be replaced only and
- Indirect waste which is attributed to:
  - ❖ "Substitution waste: when use of material is not according to the specification.
  - ❖ Production waste: when excess material is used than that mentioned in the generated bills due to onsite requirement.
  - ❖ Negligence waste: due to lack of expertise in estimating the exact amount of material that will be used in the project by the contractor or by the workers and thus additional amount used is accounted in negligence waste.

Above summarized are the various system of classification for C&D waste as observed from the literature review and highlights the idea that possibility of the C&D waste components in each project to be common, is rare. Based on the findings it is worth mentioning that classifying C & D waste can be done in number of ways but the most common approach is to classify on the basis of source and origin as it is beneficial for it provides the information about the type and nature of waste.

For example, we directly came to know from the demolition waste that it will surely be contaminated with materials like wall coverings, paints, adhesives etc. whereas excavation materials waste will be devoid of the presence of such deleterious materials and will contain basic materials like sand and aggregates and this facilitates the handling, separation and recycling of waste in an enhanced and effective manner.

## 2.5 C&D Waste Scenario in India

The quantity and variety of solid wastes generated by various sectors like industrial, agricultural, construction industry, and domestic activities, witnessed an upsurge due to Population growth, increasing urbanization, rising standards of living because of technological advancement. Globally out of the 14 billion tons estimated quantity of wastes in the year 2012, 12.5 billion tons was only the industrial wastes and remaining 1.5 billion tons was the municipal solid wastes (MSW) as per a report by world bank for the year 2012 and is expected to rise to about 19 billion tons by 2025. In this report, a study was conducted to access the global amount of solid waste generation region wise i.e the regions included under various global organizations like OECD, MENA, SAR, AFR, EAP etc. It was found by the report that almost 50 % of the waste is generally produced by the member countries of OECD organization.

Annually, 4.4 billion tons of solid wastes having 790 million tones (MT) of MSW was generated only in the Asian subcontinent and specifically talking about India, about 48 M (which is 6%) is generated in India. MSW in India would touch the mark of 300 MT by the end of year 2047 and the land required for disposal of this waste would be 170 $km^2$ as against the present requirement of 20 $km^2$ for managing the 48MT of MSW.

### 2.5.1 Indian Construction Industry

Out of the total quantum of 48 MT of solid waste generated in India per annum as per the CPCB's finding, the amount of waste from the construction industry alone is one fourth i.e 25% making it 12 MT per year. INDIA has maintained its status of being the world's fastest growing economy and this growth in economy boosted the construction industry at a very fast rate with already running at 10% of GDP for the last decade as against the world's average of 5.5%(CSE, 2013). Indian economy is divided in three main sectors i.e

1. Agricultural and allied sector
2. Industry sector
3. Service sector

The agriculture sector deals with the agriculture, forestry, livestock, and fishing etc. Industry includes mining and quarrying, electricity, manufacturing, water supply, and construction and shares 17.32% of India's total GVA and accounting 23.82 Lakh crore lakh crore. Industry sector

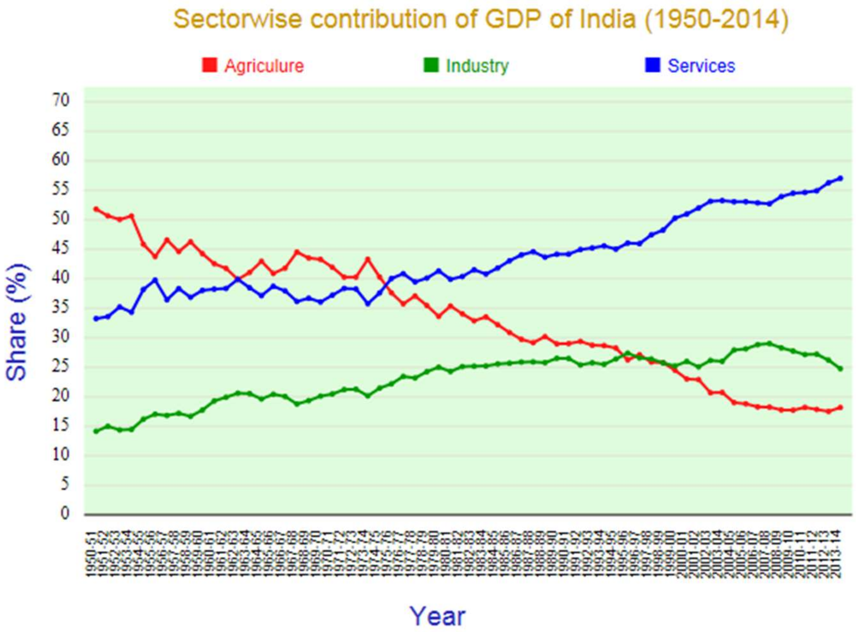


Figure 5: Sector wise contribution of GDP of India (1950-2014) (Ministry Of Statistics And Program Implementation)

contributes 29.02% towards the economy whereas the service sector is the largest sector of India on the basis of GVA (gross value added) at the current prices of 73.79 lakh crore INR in 2016-17 thus contributes to 53.66% of India's total GVA and includes all the service related aspects like trade, transportation, hotels, communication services, defense, real estate etc. Construction sector holds nearly 10% of India's Gross Domestic Product (GDP) as compared to an average 5.5% for the whole world. "GDP is the market value of all the goods and services that are believed to be officially produced in a country in given period" and is used to indicate the standard of living of any country.

Construction waste is out of the scope of disposal by the methods like incineration or composting due to its bulky, and heavy nature. Also, the availability of land for disposing the waste is becoming the matter of concern. So, we are left with Re-utilization or recycling as the most viable option or strategy for management of this kind of waste. As a matter of fact, it is the fast depleting reserves of natural aggregate that has necessitated the use of technology of recycling and re-using so that the current depleting rates can be accounted for further use.

### 2.5.2 Overview of Construction and demolition waste generation

A report on C&D waste management in various Asian countries is developed by the Asian Institute of Technology, Thailand by surveying a number of Asian countries in May, 2008. The Asian countries included in the survey were India, Bhutan, Hong-Kong SAR, Japan, China, Thailand and others. The report estimated that almost 50% of the C&D waste is contributed by the Chinese construction industry and whereas the contribution of Indian industry is merely 4% as shown by the following pie chart in Figure 5.

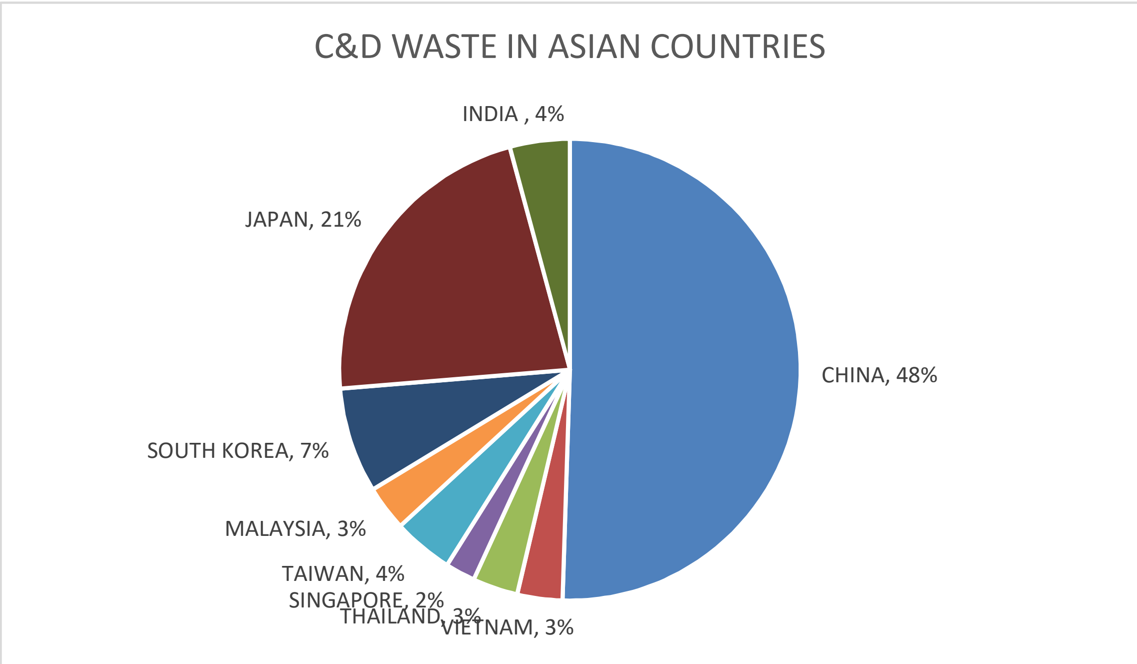


Figure 6: Estimates of C&D Wastes in Some Asian countries (AIT. 2008)

In India, it is always a matter of concern as we don't have any adequate or satisfactory data for addressing this issue. The Indian govt. always struggles for handling the construction and demolition waste as there is no separate regulatory frame work available in India, as it is considered only as a part of municipal solid waste management and no separate status is given to it up to the recent past. A CPCB report (2008) confirmed that MSW is generated at the rate of 0.53 MT per day in India and on this basis, we can say that 210 MT will the average estimate of annual waste. The estimate of C&D waste generated so far in India as per various

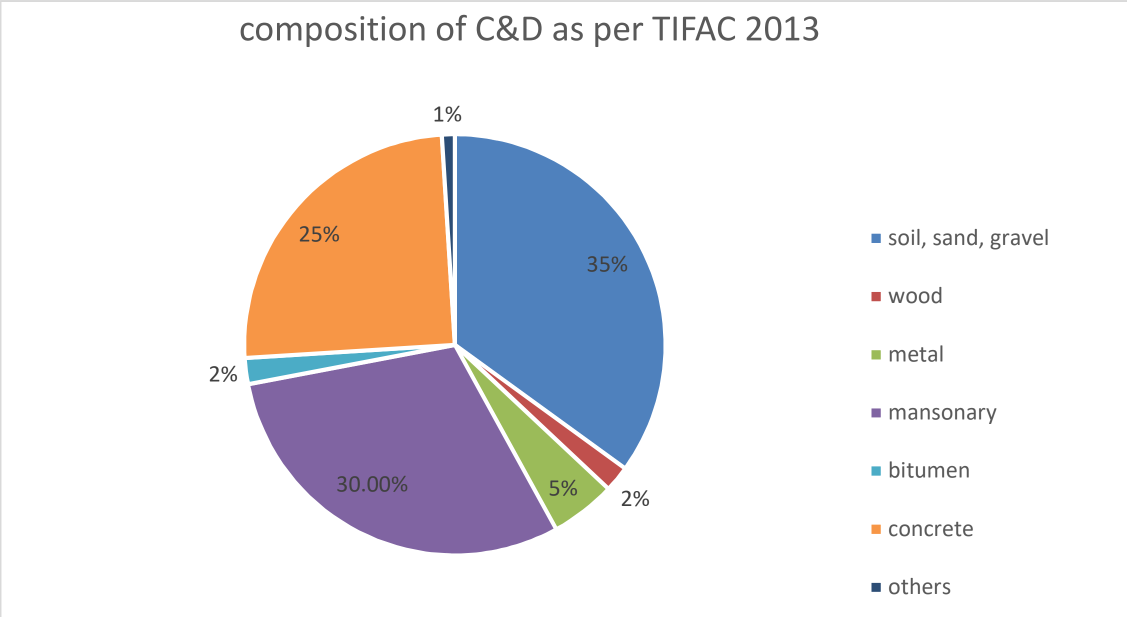


Figure 7: Composition of C&D waste (TIFAC 2013)

nodal agencies is analyzed and compiled in the form of a table number 5. But as per the world bank report, Asian countries produces MSW at an average of 0.45kg per capita per day, which is in contrast with the data provided by the CPCB thus showing that in India the management of C&D waste is always underestimated.

Table 4: Composition of C&D waste

| CONSTITUENTS | MILLION TON PER YEAR |
|---|---|
| **SOIL, SAND, GRAVEL** | 4.50-5.20 |
| **BRICK AND MASONARY** | 3.80-4.30 |
| **CONCRETE** | 2.45-3.86 |
| **METALS** | 0.60-0.74 |
| **BITUMEN** | 0.25-0.30 |
| **WOOD** | 0.25-0.32 |
| **OTHERS** | 0.10-0.18 |

*(source : TIFAC 2013)*

In 2013 a study was conducted by TIFAC, a leading institute of India known for its pioneering work of estimating the quantity of C&D waste. The aim of the study was to generate the data for the quantifying the exact scenario of C&D waste in India as before this all the estimates provided by various ministries and departments sticks to the same amount of 10-12 MT per year without accounting the fact that how in this developing world the amount of waste will remain quite same year after year. This is shown in table number 5 along with the table number 4 that represents the amount of different composition of C&D waste generated in 2013 by TIFAC. What we will call it whether a fact or an anomaly, doesn't matter but what matters is the willingness of the GOI and its allied departments and institutes. So, considering all of these factors, Centre For Science And Environment took it as a challenge and in collaboration with TIFAC worked upon for quantifying the amount of C&D waste at least so that any waste management strategy can be penned down because how finest is the technique won't work without the basic requirement of exact data.

As per TIFAC the idea of quantifying the waste is based on the following:

- New construction generates 40-60 kg per sq.m of the buildup area generating 50 MT of waste in 2013.
- 10 times higher waste is generated in demolition work as compared to new construction, thus amounting to 300-500 kg per sq.m
- It is assumed that 5% of the existing building stock is demolished and rebuilt annually leading to additional waste generation of 280 MT in 2013.
- Repairing of building amounts to 40-50 kg of waste per sq.m
- Assuming that one third of existing building stocks undergoes repairing annually thus generating additional 190 MT of waste.
- Thus, overall the amount of C&D waste generated in India for the year 2013 was approx. 540 MT which was 44 times higher than the official data

Table 5: C&D waste Estimates by various nodal agencies

| **Year** | **Authority** | **Estimate in million tons** |
|---|---|---|
| **2000** | Ministry of urban development | 10-12 |
| **2001** | TIFAC | 12-15 |
| **2010** | Ministry of environment and forest | 10-12 |
| **2013** | Centre for science and environment | 540 |
| **2014** | Ministry of urban development | No estimate exists |

# 3. WASTE MANAGEMENT HIERARCHY

Chapter 3 of the thesis provides current resources and alternatives for disposal and minimization of C&D wastes. Alternatives are analyzed to demonstrate economic benefits and limitations, and to show how geographical factors may influence the validity of specific resources. This chapter serves as the basis for chapter 4, where the technique of recycling is used by a IEISL a leading company in the field of environment and industry, promoting an environmentally sustainable solution in India.

We lack an input from the contractor in the context of design when the project is in the preconstruction phase i.e what kind of design is adopted by the contractor so a better design alternatives is not discussed here. However, various waste management issues are addressed here, such as making an order for optimum quantities of materials that are in reality required, are discussed in this chapter.

Another thing to be noticed here it that all the techniques for the waste management discussed here are independently presented without having any comparison between them. Because the thesis requires only the waste management techniques without the aim of making a choice between them on the basis of economy, feasibility or viability.

### 3.1 Different types of waste management resources

The hierarchy to be followed for classifying the waste management strategies, in order of their importance is as follows: first and fore most option we should go with is the source reduction or waste minimization based on a no. of concepts; second comes the reuse or reutilizing technique;

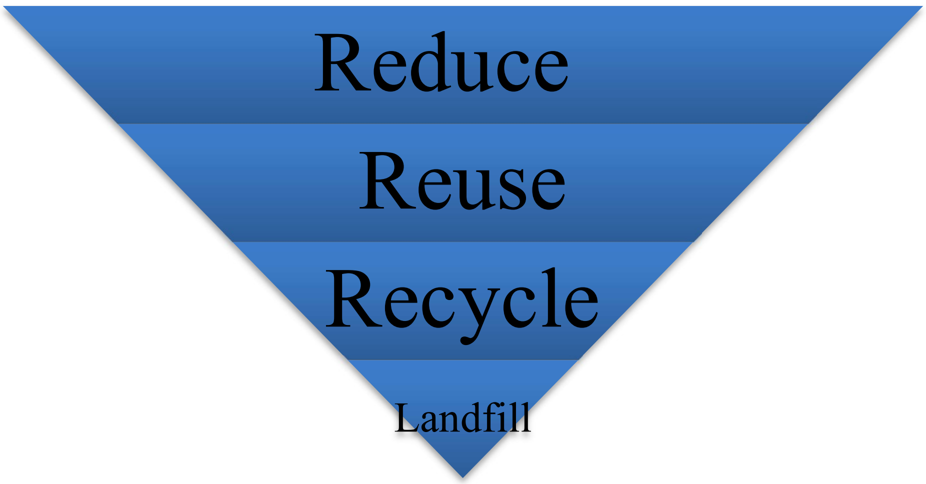


Figure 8: Hierarchy of waste management

following which comes the recycling process which is the first choice to be practiced now a day; lastly, we are left with the least acceptable method of disposal i.e landfilling which was most common till now as nothing extra is to be done to dispose the waste rather just dump the material in any low-lying area and in open air. Recycling involves just only source identification, processing, and reintroducing the waste materials back into original stream.

Reusing or salvaging possesses similarity with the recycling in terms of getting the waste back into the original stream by extraction and sorting only. The main difference between both the activities is the processing of waste to give it a new shape and form. Source reduction or minimizing the waste deals mostly with limiting the generation of waste at the source itself and making use of excess left-over material in new construction and blocking its way to landfill sites for the sake on environment and we people.

The process of Incineration, or waste to energy (WTE) is generally adopted for MSW, to get energy from the waste due to its calorific value but this option seems inadequate for the C&D waste despite they are liable of burning but how much calorific value and energy they can impart is the question here. A hierarchy for resources to be followed is given by figure 9 and it also marks the significance of waste minimization at source as the top priority which can be attributed to the only input required i.e planning. Whereas a number of inputs such as energy, transportation, or raw material usage are required by other resources and inputs blocks the way for other supplies such as electricity and fuel. This can be clearly presented by table no.7 for the inputs and their corresponding resources. WTE resources are given as the last option in the hierarchy because the sustainability criteria of development are ruled out here. The same reason is applicable for landfilling.

WTE and landfilling resources are not discussed in this section because they are very standard process and no rocket science is linked to their operation so any contractor can go for it typically. Recycling/Reuse Resources are although two separate entity but discussed here under a single head to emphasize the importance of incorporating the waste back into the resource stream whereas waste minimization is shown as separate resource.

Table 6: Inputs for Waste Management Resources

| S.no | Major inputs | Waste management technique |
|---|---|---|
| 1 | Planning | Waste Minimization |
| 2 | Energy, Transportation | Reuse/Salvage |
| 3 | Energy, Transportation, Raw materials | Recycling |
| 4 | Transportation, MSW Wastes | Landfilling, Waste to Energy (WTE) |

*( Jarman, 1996)*

## 3.2 Background of some of the Material Salvage Organizations

Any kind of project undertaken either new construction, renovation or repairing will surely generate a waste stream containing material of all type i.e whether recyclable or not. Also, there are many type of materials that have some salvage value depending upon their age and condition. Salvage value is the value of any product calculated at any time in its life span before the end of its life and there is a no. of ways to calculate it depending upon the type of material. The value of the product after the end of intended life is called the scrap value and is usually very minimal. In the demolition or repairing work we can have a no. of products that possess some salvage value for examples windows, doors, their metallic or wooden frames, aluminum cabinets and channels, plumbing fixtures like toilet pot, wash basins, sinks, bathtubs, moldings, timber used as beams and posts in wooden houses, and electrical fixtures. Very little processing can make these materials a worthwhile deed.

Other type of waste like masonry, concrete, and steel require time, space, labour and equipment to salvage. Although there is possibility of getting good returns from the salvaged material but before going to earn profit one must have an adequate knowledge of salvage organizations operating in their area. For example, there are many such renowned organizations working across USA and even in Canada out of which many organizations are nonprofitable, while others are private companies.

The material accepted by these organization undergoes sorting and is organized by the contractors for the purpose of selling or reusing in low cost housing construction. One example of such a nonprofit material salvage organization is "*The Loading Dock*" in Baltimore, Maryland. It was established in 1985 with the aim of providing affordable low cost housing to the low income group families by making use of second hand or recycled material ,(Riggie, 1992).

Within the very first year of its operation it was successful in diverting around 2000 tons of useable materials that was supposed to end in landfills; however, by the end of 1991 7000 tons of waste material possessing a retail value of around $1 million was recovered. The organization receives the material from around 200 private companies and contractors. There is mutual benefit in this as donor receives an incentive in the form of tax deduction on the costs of disposal, while the organization makes it to increase its stock that can be sold further to societies and groups like YMCA or to nonprofit housing organizations, (Riggie, 1992).

In India, we too have such organizations and firms that are making a large profit out of the waste especially in the sector of MSW. "*Hanjer Biotech Energies*" is a leading firm in India that generates Green power from the refuse derived fuel (RDF) obtained from the MSW and it installed its first plant in Jalgoan in Maharashtra which makes use of rice husk as fuel but later due to its unavailability shifted towards RDF and generated around 7MW of green energy. This was among one of the innovation in India that has helped in curbing the menace of MSW as we do have other organization working on the same like "*IL&FS Environmental Infrastructure and Services Ltd"*. (IEISL) working on the "Gazipur waste to energy plant" for generating 12 MW of electricity in Delhi.

The previous paragraph talks about the MSW processing units and business in India that are going with a right approach but the problem of processing the C&D waste still unnoticed up to 2009. It was the Municipal corporation of Delhi (MCD) that took the initiative for handling the C&D waste in collaboration with the IL&FS Environmental Infrastructure and Services Ltd and provided land and other resources to the company to set up a waste recycling facility which would be the first and leading in its own in India. So far, the results obtained are very much satisfactory as far as environment and economics is concerned.

### 3.3 Recycling of C&D waste and its potential

So far on the basis of literature review we observed variations in the composition of C&D waste that can be accrued to differences in demolition and construction techniques and differences in the type of project undertaken along with the importance of location. Thus, it is very intricate to accurately formulate a common list for all the components of C & D waste arising for all types of activities worldwide. How-ever it is practically possible to list down a number of components that are expected to be common to majority of the construction projects up to certain extent such as:

- Concrete and Masonry (bricks and mortar)
- Wood, Paper and cardboard
- Metal ferrous (Steel) and metal non-ferrous (Copper, Aluminum)
- Plastic (PVC pipes, plastic films for packaging, wall coverings)
- Glass and Ceramic tiles
- Insulation material (Styrofoam and mineral wool insulation)
- Drywall/gypsum board
- Filling material (gravel, sand and soil)
- Marble and granite

It was a matter of concern for the whole world to investigate and search about the potential of recycling of C&D waste for over more than last five to six decades. Concrete, a basic component of C&D waste for example can be recycled easily and can supplement the natural aggregates in almost every project and this has been confirmed by a number of leading institutes like the American society for testing and materials(ASTM) and American Association of State Highway and Transportation Officials(AASHTO) and Bureau of Indian Standards(BIS) to use the recycled aggregates in new construction.

The Wood waste obtained can have a no of direct or indirect applications. The direct application asks for reusing the wood present in the form of doors, windows, beams etc and as described in above sections. While indirect use calls for recycling the wood to use in a no. of applications like as a mulch, in soil amendment and in composting, in paper and pulp industry or lastly as a fuel in industry. Similarly, we can use the masonry bricks either in original form like in boundary wall and in foundation course or we can recycle it to form the brick sub base aggregates of varying sizes or the surkhi powder and thus have a suitable applicability in industry.

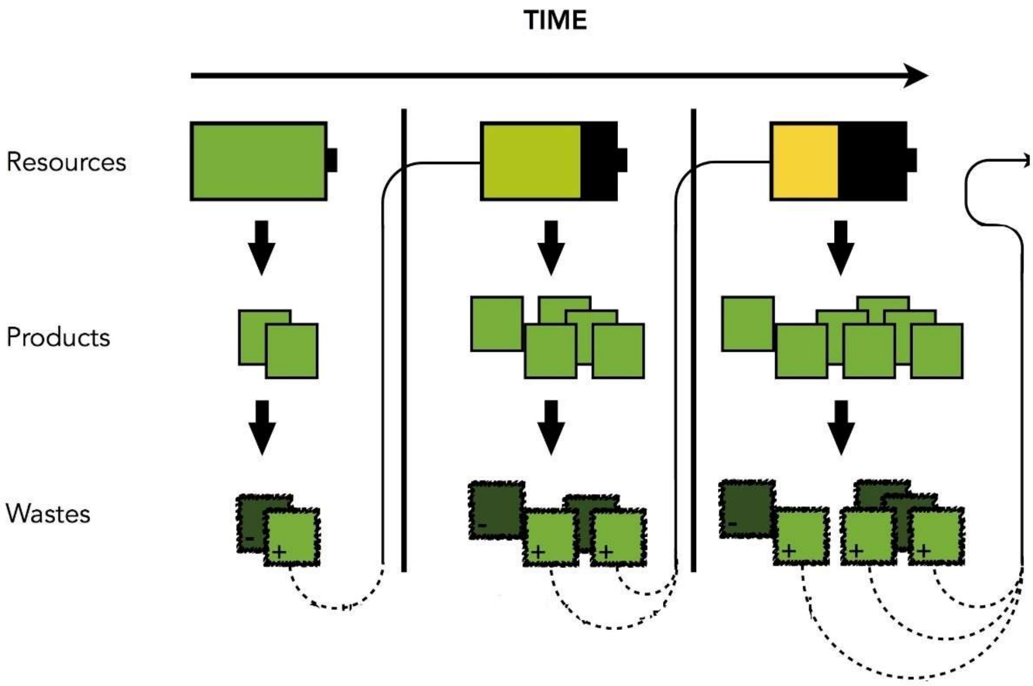


Figure 9: Flow chart for recycling of waste (Wikipedia 2002)

On the basis of literature review and the conscience of author, a system of ranking the recycling potential of C&D waste can be generated where a ranking is given to different components of waste according to the ease of recycling. The ranking scale used ranges from a score of one to five. Score 1 is given to the material having least recycling opportunity and is tough to recycle, whereas higher score of 4 to 5 indicates an ease in recycling and hence more feasible is its recycling. As indicated by table no 8. It is clear that recycling of ferrous metals, non-ferrous metals, papers, cardboards etc can be done efficiently and can produce a material of same value and composition.

Recycling of materials like Concrete, ceramic tiles and glass is yet not fully optimized in terms of technique, efficiency and effectiveness so they are put next in the list after wood and paper. The biggest problem with the recycling of masonry and marble waste is the amount of fine dust and powder generated while grinding and crushing thus causing problem in their recycling. The lowest score is given to the gypsum board and insulations like Styrofoam and mineral wool, indicating that their potential for recycling is least and also the quality of recycled material is very poor.

Table 7: Ease of recycling of different waste material

| Waste material | Score (1-5) |
|---|---|
| **Concrete** | 4 |
| **Wood** | 3 |
| **Ferrous metal** | 5 |
| **Non ferrous metal** | 5 |
| **Masonary** | 3 |
| **Plastic** | 3 |
| **Glass** | 4 |
| **Ceramic tile** | 4 |
| **Mineral wool** | 2 |
| **Styrofoam** | 2 |
| **Drywall** | 2 |
| **Filling material** | 3 |
| **Paper** | 5 |
| **marble** | 3 |

*(Sally M. Elgizawy,2016)*

Table 8: Possible recovery option for C&D waste source

| WASTE | RECOVERY POTENTIAL |
|---|---|
| **Concrete, clay and bricks** | Can be crushed, afterwards used as artificial gravel for road construction and road filling; reuse possibilities of 50% |
| **Wood** | Raw untreated wood usually rafters and ties has a 10-20% potential of recovery |
| **Metal** | Usually studs and structural elements; in office and residential buildings 10% of metal elements are capable for reuse |
| **Mineral wool** | Reuse possibilities with small remanufacture activities; remolding in new mineral wool material or torn into loose material wool; 90% reduction of energy consumption compared to production of new mineral wool |
| **Glass** | It can be recycled in a no. of ways; reuse of glass is limited to reuse in windows and door elements. |
| **Plastics** | It is mainly recycled; direct reuse of plastic is not common due to erosion and damage; |
| **Gypsum** | Has reusing potential of up to 25% as dismantled gypsum boards used in inner walls |

*(Thormark, 117-118)*

Thermal insulation is type of building insulation that helps in maintaining a constant temperature in building and thus reducing the surplus loss and gain of heat and accordingly decrease the demand of energy. The material for thermal insulation can vary in composition as per the requirement and some of the examples are Styrofoam, mineral wool fiber etc. Styrofoam is a type of insulation applied at the walls, floor and roofs of the buildings and also it is an excellent packaging material for the electrical appliances and is extensively used in the disposable items like cup, glasses and plates.

Mineral wool is an inorganic compound formed by addition of 4% of volcanic rock or basalt with 95% of blast furnace slag in the presence of some binder like urea-phenol-formaldehyde based solutions. Mineral wool is chiefly used as a thermal insulation, fire protection, noise insulation in the buildings and constitutes for 0.2% of C&D waste. Due to its contaminating property when heated in the air, it poses the greatest problem in recycling and thus we are left with the only solution of landfilling, which also is not a very feasible solution but nothing more than that can be done.

### 3.4 Waste minimization resources

It is the last decade when the increasing problem of waste generation and its impacts on the environment and society is taken seriously and in its reply a no. of concepts and approaches are introduced. This section in this chapter will cover the waste minimization and recovery options in a chronological way and according to their relevance. The concept of circular economy or zero waste management is highly relevant from the point of view of the knowledge gained by reviewing the literature and is discussed after the concept of cradle to cradle and life cycle thinking because circular economy concept is based on both the above-mentioned concepts.

#### 3.4.1 Cradle to cradle: Regenerative design

Michael Braungart and William McDonough were the first in 2002 to develop the concept cradle to cradle so as to bring effectiveness in the approach of the zero-waste generation. It is a Bio-inspired approach of designing the systems and processes. It is based on the replica of environmental processes that act as a model for the human industry like the process of material flow is assumed to be the nutrients recycling in a health manner. It focuses on protecting and enriching the ecosystem and nature's metabolism along with maintaining the technical ecosystem for desired quality and quantity control in industries and to seek a system that is efficient and waste free.

In 2002 Braungart and McDonough published a book titled "***cradle to cradle: Remaking the way we make things"*** which is a manual providing specific details of how to incorporate this concept in any of the design and process. The same logic is used here to provide an interface and link in the various components of the industry so as to promote the goals in term of society, and environment. According to the concept all the material that are to be used in the industry can be classified under two heads i.e "biological and technical nutrients". In the technical nutrients, we place all those synthetic materials that are nontoxic, non-harmful and

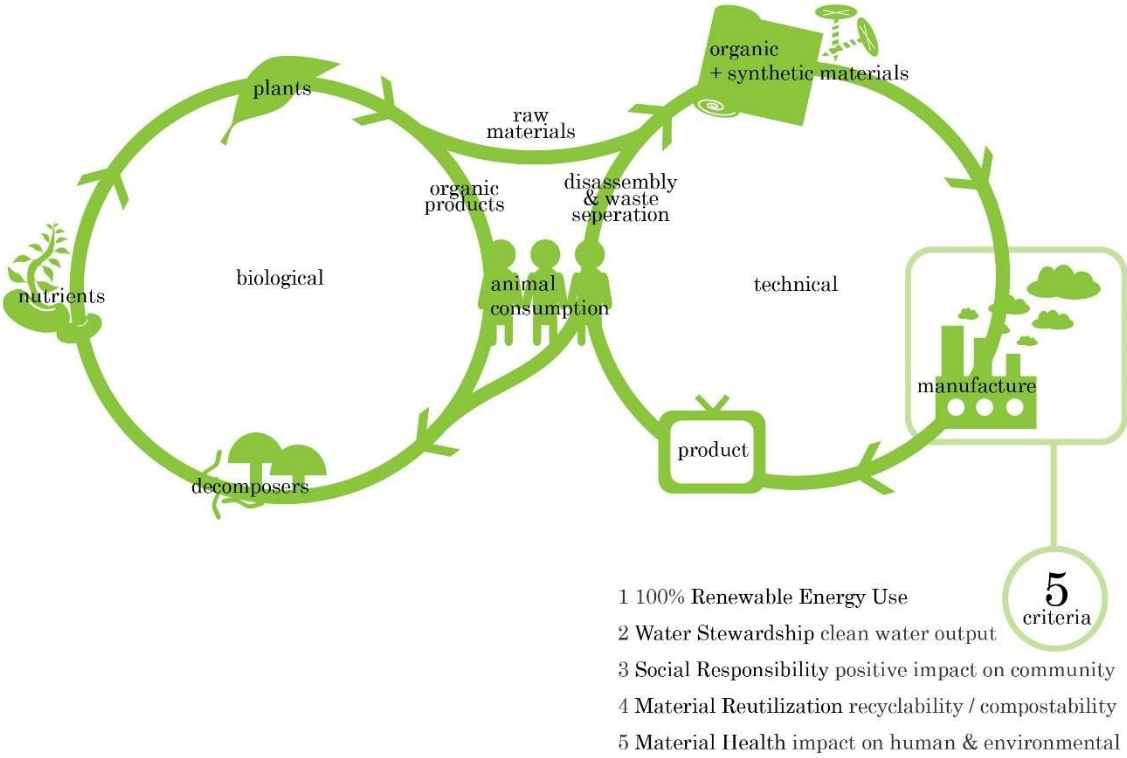


Figure 10: Biological and Technical cycle in C2C

that can be recycled as the same material without losing its value and integrity. Thus, promoting the use of materials again and again without the possibility of down cycling or becoming a waste. Whereas biological nutrients refer to the organic materials that have regeneration capability if disposed in any natural environment and serves as a food for other life forms without harming the environment.

C2C paves the way to promote eco-effectiveness between various interdependent natural and industrial systems such that a waste for one process can be used as a resource for another. Eco-

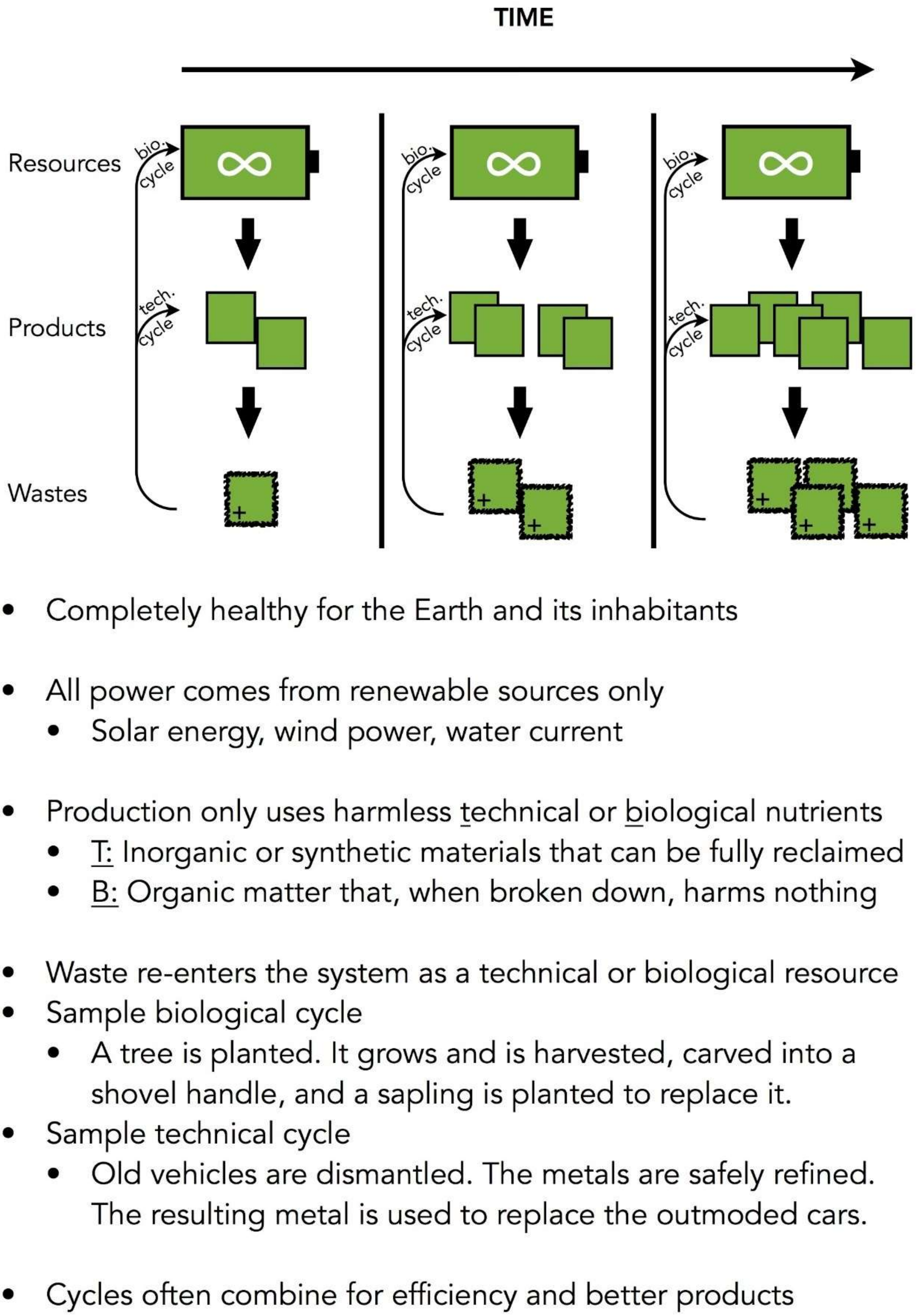


Figure 11: Cradle to Cradle approach for waste minimization

effectiveness differs from the concept of eco-efficiency which is a linear approach, as it is a circular system for reintroducing the output in the input. Thus, it is required to change the way designs and processes are working currently such that any harm can be avoided at the early stages of planning itself. It is marked by Braungart ***"being less bad is no good"*** i.e we should focus on doing better by doing well.

### 3.4.2 Life cycle analysis

It is a tool for assessing the impacts of any material during any stage of its life on the environment. It can be from material extraction through material processing, manufacturing, transportation, use, repair, disposal. This tool is used by various industries and product designers to evaluate their products in context of environmental harm as LCA provide a broad view for analyzing any product as follows:

- An inventory is compiled dealing with the various inputs and possible outputs
- Evaluation of all the possible impacts on environment
- Lastly interpretation of the results for taking an informed decision.

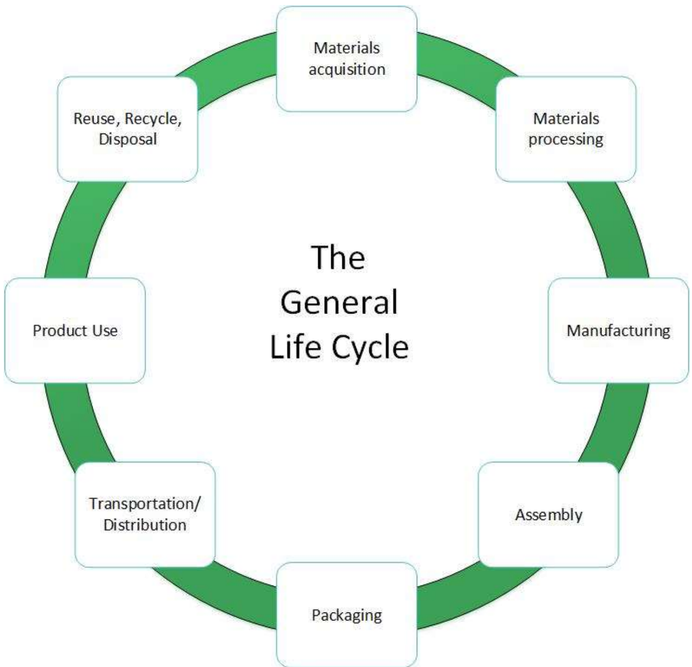


Figure 12: The general life cycle of any product (Wikipedia)

The goal of LCA is to conduct a full featured comparison of all the environmental impacts caused by the products and services by identifying all the inputs and outputs as the material flows through different phases of its life. The information obtained from the LCA is used in designing an environmental sound policy and in improvised decision making. The term Life cycle used here indicates that a fair assessment at all the steps through which the material flows in its life is needed ranging from extraction, to processing, production transportation, use and lastly its disposal. There are three main types of LCA tools available and are as follows:

1. Attributional LCA's: - It always seeks to attribute all the load that is associated with the manufacturing and use of any product at any point of time in its life.
2. Consequential LCA's: It deals with finding the environmental consequences of a decision taken by any industry, in context of market and economic implication that it will bring.
3. Societal LCA's: - This type of LCA is under development and is intended to assess the societal implications and impacts of any project and this will work in complementary to environmental LCA.

ISO 14000 dealing with the environmental management also deals with the procedure of LCA and helps the organizations to minimize their potential impacts on environment, to comply with the standards, laws and regulations and finally to improve them on a continuous way.

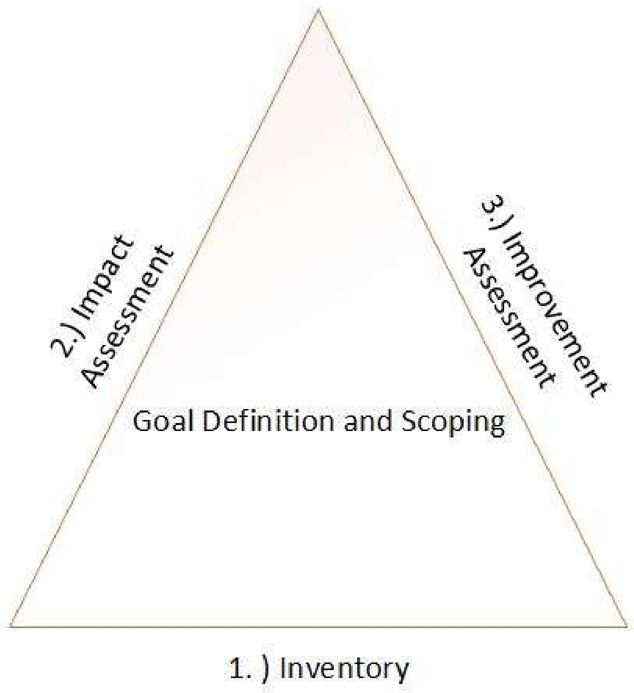


Figure 13: Phases of LCA ( Wikipedia)

#### 3.4.2.1 Phase of LCA: -

The life cycle assessment is conducted in four different phases complying with the standards of ISO 14040 and 14044 as illustrated in figure 14. All the phases of LCA are interdependent as the result of one phase will guide for completion of the other phases.

Goal and scope: -

- Defines purpose of the activity i.e why do u want to carry out LCA
- To define the life cycle of product or material
- To recognize the material flow pattern
- To define the boundary conditions

Life cycle inventory: -

- To create inventory for the purposed flow of material to and from the nature
- Define scope and boundaries
- To gather data about the inputs and releases and to develop a model
- Analyze and report the study results
- Various LCI method are process LCA, economic input output LCA and hybrid LCA (source Wikipedia)

Life cycle impact assessment: -

- To characterize and assess the effects of resource requirement
- To identify environmental loading
- Address ecological and human health consideration.

Interpretation: -

- To summarize the result of inventory and impact assessment.
- to quantify, check, and evaluate information from the results of the life cycle inventory and/or the life cycle impact assessment.
- Conclusion and recommendation are made finally after interpreting.

#### 3.4.2.2 LCA and C&D waste: -

We too have the applicability of this LCA tool in the case of the construction industry dealing with the construction and demolition waste. Using this we can assess the potential impacts of the C&D waste on the environment and it only requires the knowledge of different stages in the life of the building material through which it passes. The different stages in the lifecycle of a building material and associated inputs and outputs is discussed as follows:

**Resource extraction**: what it requires as input for extracting the virgin material and how much it affects the surroundings.

**Transportation:** various inputs and outputs that should be provided are fuel consumption, energy required, $CO_2$ emission, etc while transporting the waste from one site to the recycling facility.

**Energy consumption:** At the recycling facility which type of machine is used i.e whether electrically operated or diesel operated and how much energy they consume and all such data is required as an input.

**Facilities at site:** It includes all the activities that is in one or many ways associated with the energy consumption, resources consumption and gaseous emission like water required, pre-treatment activities carried out and landfilling etc.

### 3.4.3 Circular economy

The concept of circular economy is based on the analogy executed by the natural system of material flow. The aim of the concept is to develop such an economy where material utilization is maximized along with waste minimization. This can be achieved by the closed loop flow, where an additional value can be extracted from materials by their successive passage to act as a resource in another circle. This system is better than the concept of linear economy where the flow of material is unidirectional and lastly it will end up as a waste.

This concept was first applied by the Chinese govt. in 1998 for developing an environmentally sound strategy for management of pollution and to support the sustainable development. The key principle of circular economy i.e to maximize the resource utilization by making a change in input/ output to processes, was the core of Chinese strategy. This model was implemented by the Chinese govt. in their political agendas and was focused on the ecological principle of material management.

This concept can be suitably applied to the industries whereby a continuous availability of material is ensured without having any loss in value of material. The design of product is such that it can undergo further treatment and a possible reuse after slight processing. Thus. marking a strong difference b/w the definitions of material consumption and material use. The consumption of material is an example of linear economy where the inevitable fate of material is unidirectional and can't be put back in the same system. Whereas material use deals where the ownership of any product is retained with the manufacturer and they only act as a service provider who sells their product not their consumption (Ellen McArthur foundation 2013).

A paradigm shift can be made from linear economy approach to circular economy by improving the whole system rather than investigating the ways for improving only a single component and thus enabling the products to have a circular design. For building the natural and social capacity, a system that enables effective and efficient flow of material, information, and manpower is of utmost importance.

Furthermore, the concept makes a clear-cut distinction b/w two type of nutrients flow i.e the biological nutrient and the technical nutrient. The biological nutrients are those nutrients that can harmlessly circulate in the biosphere and help in regenerating natural capital. While technical nutrients are those materials that doesn't enter the biosphere, but circulates at a high quality (Ellen McArthur foundation, 2013). Thus, the natural and artificial components circulation in a same economy have different functions and they should be considered as separate entity. The natural components can easily re-enter the system either by composting or by anaerobic decomposition but the technical nutrients are designed for recovering purpose with a minimum energy input and gaining max. value as output.

It is important to notice here that the circular economy concept is a different approach as compared to the circular loop system. As the product in a linear economy are designed for consumption only thus have a short lifetime and are left with the only possibility of recycling at the end and thus faces a huge loss in its value. The circular economy model relies on the very first principle of making such design of product that enables them to regenerate and to return into the economic cycle by withholding the same value as before and in cascade it should treat every component as a valuable entity for other circle of economy.

However, this value restoration is possible by following the guidelines as stated below: -

- By transforming the waste into useful products and using it in other circle of economy, thus maintaining their value.
- To improve the whole system for maintaining the effectiveness rather than focusing on individual parts.
- By keeping the material for a longer duration in the circle.

### 3.4.4 Delimitation of waste minimization techniques

While making a comparison in above three concepts, we found basic similarities as they are somehow interrelated to each other. For assigning relevance to the concepts, which is a subject of this research, the following parameters are used for discussion and same is depicted in table no 10.

1. **Approach**: - Both C2C and CE holds similarity on the basis of the principle of circular system, but aim of C2C is to strictly adhere to a zero-waste strategy working in a closed system and that of CE is to design the product in such a way that value of material is maintained along with additional value creation while circulating in closed system. LCA focuses on the life cycle of products and processes and to identify the source of environmental impacts and how to reduce them.
2. **Audience addressed**: - The C2C addresses all the businesses and manufacturers to promote synchronization b/w various businesses for doing good to environment beyond their own interests. CE addresses the society and businesses to come up with a design that promotes circular system with focus on value creation. LCA asks the manufacturers to take the main responsibility and work on the principles like extended producers responsibility(EPR) or polluter pays principle(PPP).
3. **Focus**: - C2C focuses on promoting business synergies with the aim of waste minimization. LCA focuses on to carry out environment impact assessment(EIA) at all the stages of a material life to identify the sources of pollution. CE focuses on material value restoration and creation.

Table 9: Comparison of different waste minimization techniques

| **Parameter** | **C2C** | **LCA** | **CE** |
|---|---|---|---|
| **Focus** | Circular system, eco-effectiveness | Life cycle stages | Circular system and cascades |
| **Aim** | Zero waste, closing the loop | Identifying and reducing environmental impacts | Intentional design, value upkeep and creation |
| **Addresses** | Business, manufacturers | EPR, PPP and manufacturer | Society and business |
| **Assesses** | Business synergies to promote a closed system | Management of complex environmental impacts | Design and value |
| **Indicators** | Biological and technical metabolism | Inputs and outputs | Biological and technical (manmade) nutrients |
| **Approach** | Pro-active | Pro-active and re-active | Pro-active |

*(Bruckmann, 2013).*

# 4. CASE STUDY OF IL&FS C&D WASTE RECYCLING PLANT

## 4.1 Introduction: -

IL&FS is considered as a frontrunner company in terms of project like transportation, energy, water, financial services, environment and skill development etc and has maintained its status of being a pioneer in implementing PPP models efficiently in India. The main aim of IL&FS is to invest in sustainable infrastructure and environmental development programs and has proved it by involving in PPP models for the sake of nation building.

It aligned itself with the national missions for development in India like skill development, infrastructure development, waste management, clean development mechanism by coming in a collaboration with 22 Indian states. Success in any project can be achieved by having a strong contribution from the stakeholders and shareholders and this is done by IL&FS in all its projects and got full support from its partners like govt., financing agencies and private sectors.

## 4.2 IL&FS Environmental Infrastructure & Services Ltd. (IEISL): -

IEISL is an enterprise of IL&FS dealing with projects associated with the environmental management. It has an experience of around 2 decades for providing end to end solutions and in integrating environmental considerations in decision making across various sectors. The company partnered Ministry of Environment, Forest and Climate Change (MoEFC), US Agency for International Development (UDAID) and launched successful programs like "*Kottayam Ecocity initiative*".

In context of environment and its protection, a no. of steps is taken by the IEISL and are as follows: -

- A composting plant from the MSW obtained from the vegetable market at Okhla in Delhi.
- Becomes a leading carbon financing industry in India with the treatment of 11000 TPD of MSW per day all across India.
- It has established a WTE plant in Ghazipur, Delhi for processing more than 2000 TPD and helped in mitigating 8.2 MT of Green House Gases (GHG'S) emissions since its inception.
- The next in trade is the Construction and Demolition waste recycling plant at Burari in Delhi working at a capacity of 2000TPD and has helped in saving 45 acres of valuable land in Delhi

amounting INR 450 crores.

- It has taken an initiative of managing the solid waste generating in Varanasi, Uttar Pradesh by reviving the dormant composting facility and by running awareness programs.

### 4.3 IL&FS C&D waste recycling plant Delhi: -

In 2009, a C&D waste recycling facility was established at Burari in Delhi with the combined efforts of IEISL and Municipal Corporation of Delhi (MCD) on a pilot scale basis to streamline the management of C&D debris arising in areas under the jurisdiction of MCD. Initially it was designed to operate at the capacity of 500 TPD but later on the basis of its performance and technology improvement the operating capacity is increased to 2000 TPD.

MCD approved and provided 3 acres of low lying land at Burari for the C&D facility for a period of 10 years and on the condition that land will be returned to MCD after the completion of tenure. In order to improve the collection of C&D waste, MCD proposes plans of engaging private contractors in this work of collection and dumping. Later on, the bifurcation of MCD in three zones i.e North Zone, South Zone and East Zone, the jurisdiction of plant comes under the North MCD (NDMC) and it receives the waste from major zones like Karol Bagh zone, Saddar Paharganj zone, City Zone, Rohini Zone, and Narela Zone. During the 2010 Commonwealth Games, 2 lakh ton of C&D waste was collected from the streets of Delhi and was dumped at the plant for further processing. Till now the plant has processed 28 lakhs of C&D waste since its inception in 2009.

This plant works on the principle of Cradle to Cradle concept of waste minimization as the material is undergoing downcycling whereby its value goes on decreasing after recycling. But it is still better to go for downcycling rather than to dump it in landfills. A no of recycled products obtained from the waste makes it way to further use like that of concrete bricks for the new complex of Supreme Court of India, paver blocks and kerb stones are used in the road side works, the aggregates are used in the new constructions. Various materials obtained are: -

- Stone aggregates of all sizes
- Granular sub base
- Surkhi powder
- Loose soil
- Paver blocks
- Tiles

- Kerb stones etc.

**4.3.1 C&D waste Recycling and Reuse Process: -**

The recycling process of waste is a little tricky process and it needs to pass through a no of steps in a chronological order. On the basis of the incoming waste different approaches for treatment is used i.e for the concrete waste dry process is used whereas for the mixed type of waste wet process of treatment is adopted. Both these processes have their own advantages and disadvantages The overview of the activities that are common to both the processes of C&D waste recycling are classified as:-

- Weighment ·
- Manual Segregation ·
- Screening, Crushing and Washing.
- · Casting Yard ·
- Quality Testing and storage ·
- Sales and dispatch

### 4.3.2 Wet process of recycling

For processing the mixed type of waste wet process of recycling is preferred where it is ensured from the very first step that the waste should be wetted enough so as not to pose any air pollution. For this purpose, water sprinklers are installed at every location of CDE-Asia plant. The output of this process (granular sub base) is different to that obtained from the dry process (stone aggregates).

### Overview of process: -

- Mixed C&D as segregated above would be fed to the Hopper provided with a Vibrating Grizzly that is equipped with a 60-mm opening grid for batch-wise processing. Where the -60 mm fractions are directly sent for wet processing and +60 mm fractions to crusher for size reduction.
- The wet processing consists of grizzly, log washer, vibro screens, Evo wash, thickener that is capable of segregating sand from mixed C&D waste and is designed for feed capacity of **60 Tons per Hour** (TPH) and sand washing capacity of 40 TPH.

- Whole and broken bricks are manually segregated near the feed platform and used for internal construction purposes or shall be sold directly to the customer.
- C&D waste like mix concrete and bricks, sand is fed into the CDE-ASIA plant and obtained in the form of BSB +20mm, BSB 10-20mm, BSB 5-10mm, BSB powder and sludge.

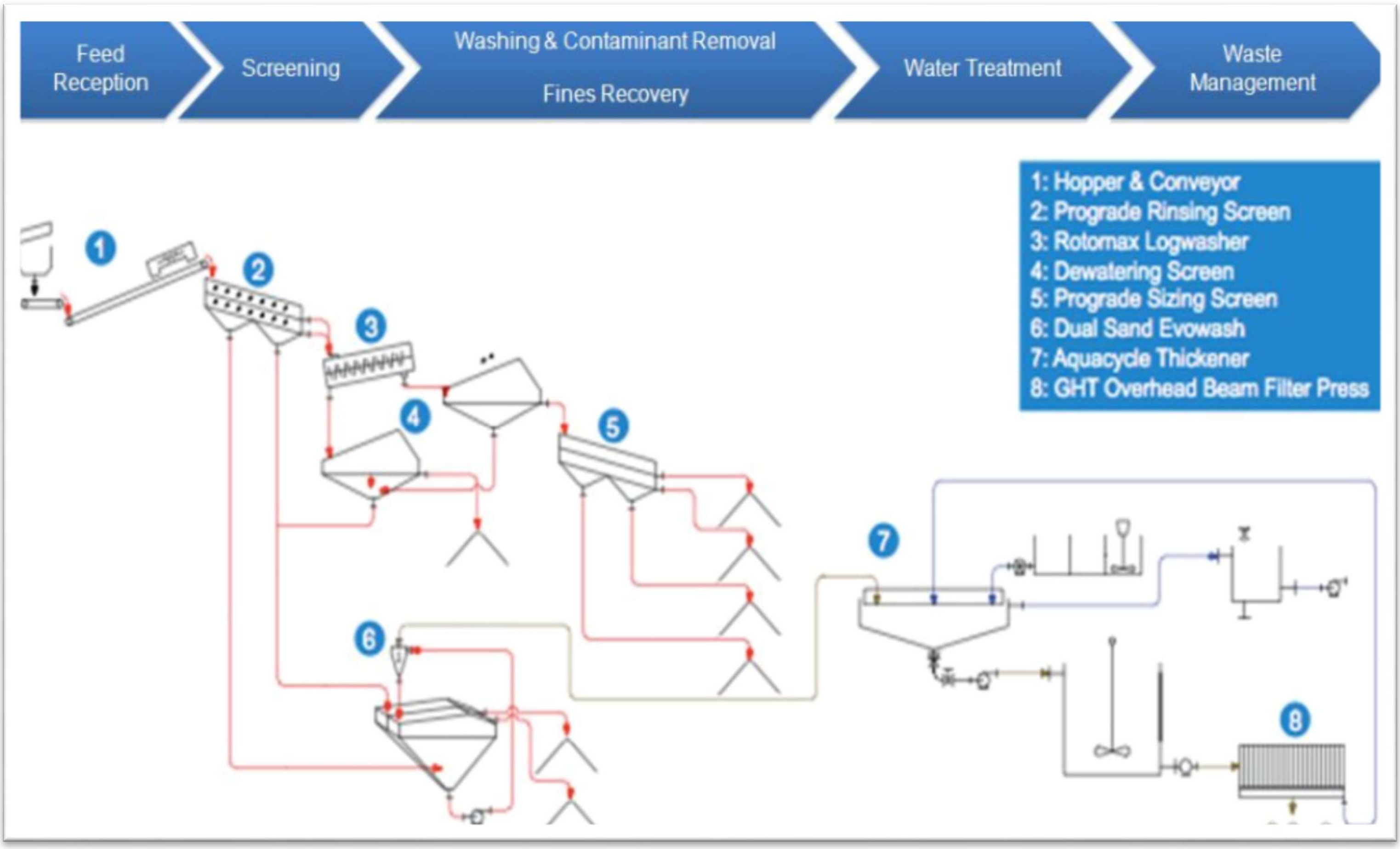


Figure 14: Overview of wet process of waste recycling

1. Feeding waste into grizzly: -

- All the incoming materials after weighing is dumped at the receiving platform.
- The dumping platform contains the feeding grizzly in which feeding will be according to the size of waste fractions.
- All the cement blocks which are more than 200 mm size are manually separated and fed to the impact crusher.
- All the materials which are less than 60 mm would pass through a grizzly and take it to the main conveyor belt

2. Impact crusher: -

- Impact crusher is a heavy-duty crusher with a capacity of **50 Tons per hour** which crushes the waste materials to less than 20 mm size aggregates.
- This input feeder will send the materials into a separate Impact crusher for further reduction of size upto 1/10 of original size (i.e) approximately 20 mm size
- The output of the crusher would be taken to the main conveyor belt which feeds it as an input to the prograde screen.

3. Main inclined conveyor: -

- Inclined conveyor is fitted with a belt of 0.8 meters width and 35 meters length and is fitted with a motor having capacity of 7.5 Horse power.
- The conveyor belt from the hopper system and the output stream from the impact crusher will be feeding the materials into the main inclined conveyor.

Figure 15: Main conveyor belt at IL&FS Plant

4. Prograde Screen: -

- Prograde consists a free oscillation chamber fitted with wire mesh of various sizes to screen the input materials.
- All input material is fed to the oscillation chamber from the main inclined conveyor belt.
- A Spreader plate located on the oscillation chamber will uniformly distribute the input materials over the screens so that optimum utilization of the screening chamber is obtained.
- A deck supporting 3 layers is fitted for screening the waste falling in the size range of <5 mm, 5-10 mm., 10-20 mm and > 20 mm .
- Washing unit with set of pipes is attached with the chamber for washing the waste so that soil can be removed from the surface of GSB material.
- Discharge channel is provided at the end of each deck to collect the screened materials and sent to the desired location through a mobile conveyor.
- Water collected after the cleaning process will be in the form of slurry. This slurry will be passed onto the aqua cycle unit for further processing.

Figure 16: Prograde Screen at IL&FS plant

5. Mobile conveyor for discharging the output: -

- Mobile conveyors are fitted at the discharge end of the prograde screen for collecting the screened outputs.

- They are fitted with a belt having the width of 0.6 mtrs and 11 meters length and a motor capacity of 5 Horse power.
- Mobile conveyors are provided with a rubber tyre and axle so that the direction and height can be adjusted to unload the screened materials at the designated location.

Figure 17: Discharge mobile conveyors belts at IL&FS plant

6. Evo wash: -

- It is a washing basin for the slurry discharged from the prograde screen and act as a silt cut point that helps in preventing the loss of fine aggregates to the settling basin in the next process.
- Currently the maintained capacity of sand washing is 250TPH by using a single Evo wash unit.
- The Evo wash sand washing system has replaced the traditional systems such as bucket wheels because it has the capacity of removing even particles of size less than 60 microns.
- A sand separator in evowsah works on the principle of centrifugal force to separate the sand from the water and can separate the sand either in tank or in the bottom of well in as of in well separator.
- It is used upstream of a filter to remove the bulk of the contaminants, as it doesn't have any screening to act as a filter. Thus, it helps in reducing the time and increasing the efficiency of process.

Figure 18: Evo-wash and sand separator at IL&FS plant

7. Aqua cycle: -

- Aqua Cycle is a cleaning filter plant which collects slurry from the screening chamber and separates the sludge and water.
- Slurry from the screening chamber is fed into the overhead tank through an separate inlet pipe and Sludge gets deposits at the bottom of the tank.
- Clean water overflow through the top edges and collected in the separate chamber and pumped into screening chamber for further cleaning.
- Sludge deposited at the bottom would be pumped out at regular intervals and deposited in the lagoons.


Figure 19: Aqua cycle at IL&FS plant for Settling of Suspended Soil

8. Flocculation: -

- It is a process where a coagulant in the form of a chemical is used to enhance the particle settling in the tank. The chemical used here is a heavy chain polymer namely "Polyacarylamide".
- This polymer dosing system is widely used throughout the quarrying industry for promoting the settling of silt from the waste water before draining it out.
- The basic operation is to take water from storage tank and mix with a polyelectrolyte material in a certain proportion and then transfer the mixture to a storage tank from where it is dosed in the aqua cycle for achieving fast thickening process.
- The chemical used (Polyacrylamide), is the industry standard for industrial water treatment. The same chemical is used in the treatment of municipal water for drinking in almost all water work throughout the world.
- The row **Polyacrylamide**, is in powder from and for correct management and storage it should be stored in the supply cabin

Figure 20: Flocculation chamber for storing the Flocculent at IL&FS plant.

9. Filter press: -

- To separate the soil from an aqueous system a filter press is used as a tool which is based on the principle of compression by applying air pressure fully.

- It works only batch wise i.e the next process can start only after the fully loaded press is first emptied to discharge the solid cakes of soil and water separately.
- Skeleton and filter pack both are the major components of a press where the filter pack is held by the skeleton and pressure is being developed inside the filtration chamber.
- The slurry from the tank is pumped to the center of the press and from here it is distributed to each chamber on its own
- The process of filling the press should be carried out at a faster rate to avoid the formation of cake in first chamber without filling of last chamber.
- The pressure inside the system tends to increase in due course of filling of chambers because the formation of cakes has initiated.
- Then, the liquid is extracted out from the filter cloths when subjected to compressed air pressure thus making this method much more cost efficient.

Figure 21: Filter press for separating suspended soil from water.

### 4.3.3 Casting section: -

Introduction: -

- The process of making nonstructural units out of the C&D waste after recycling it is carried out in this section.
- Thus, the recycled aggregates find a way in the form of products like paver blocks, chequered tiles, concrete bricks, kerb stones etc.

- Also, there is a raising demand for the recycled aggregates and bricks sub base obtained in loose form from dry and wet process respectively.
- Since we have a casting facility present at the plant, this in turn proves to be a source of revenue generation.
- According to the user’s demand, a no. of products with varied strength, color, weight, and size is casted.

### Checks before starting: -

- Check for the cleanliness of the work environment before starting the operation.
- Check for the enough space for unloading the concrete mix.
- Check for the vibrator table functions.
- Check for the required quantity of PVC cast molding frame.
- Check for the function of hydraulic hollow bricks machine.

### Operation for paver block & tiles:-

- Transit mixer will unload the mixture at the designated location in the casting yard.
- Cleaned casting blocks will be kept at the side of the vibration table.
- Loader will lift the concrete mixture using the shovel from ground to vibration table.
- Fillers will fill the molding block lined up in the vibrating table and push into vibration table.
- Vibration table will compact the filled-up PVC blocks by continuous vibration.
- At the end of the table, stacker will collect the filled compact blocks and stack at the designated location using the ply board as separator. After the blocks have been dried usually in one or two days depend upon the climate, it will be carved out manually.
- All blocks will be passed through the curing process of spraying the water for 7 days for 3 times in a day.
- After the curing process, all the blocks will be sent to the storage yard.

### Procedure for colored paver block & tiles: -

- Aggregates of 5-10 mm, cement and sand will be unloaded at the designated location in the casting yard.
- Water and coloring pigment will be added manually and mixed with a mini mixer machine.

- Mixed material from the mini mixer will be transferred at the designated location in the casting yard.
- Cleaned casting blocks for manufacturing will be kept at the side of the vibration table.
- Loader will lift the concrete mixture using the shovel from ground to vibration table.

Figure 22: Casting section at IL&FS plant

- Fillers will fill the molding block lined up in the vibrating table and push into vibration table.
- Vibration table will compact the filled-up PVC blocks by continuous vibration.
- The filled blocks will automatically move to the end of the table by the action of vibration.
- At the end of the table, stacker will collect the filled compact blocks and stack at the designated location using the ply board as separator.
- After the blocks have been dried usually in one or two days depending upon the climate, it will be carved out from the mould.
- All blocks will be passed through the curing process by spraying the water for 7 days for 3 times in a day.

### 4.3.4 SAFETY ISSUES: -

The major issues regarding safety addressed by the plant are: -

**Personal safety**: -

- Masks, Helmets and shoes: Employees are supplied with the helmet and shoes for the personal safety.
- Goggles: Special types of goggles are used while performing welding, grinding or similar activities.
- Gloves and fire safety jacket: Special type of gloves for handling hot systems and also jacket for safety when working inside the hot region like when drilling out the ball formed in the kiln.
- Safety belts: While working on the altitude special kind of belt is wrapped to prevent the probable accident.

**Plant safety: -**

- Emergency switches: In case of any urgency in any sector of pant like if someone got stuck in the machine or some serious machinery problem arise then the emergency switch can be pressed to react against it. In every localized region, this switch is present.
- Plant trip: In case of any value of temperature, pressure or vibration exceeding the set point or trouble in any part within the plant may result in entire plant trip, this is a PLC system built within the plant for logical reaction for unseen problems.

**Fire safety:**

- Type A, B and C fire extinguishers are placed in the office sector and other parts of the plant to react instantly against the fire.

**Communication system:**

- Radio phone: This is for instant delivery of message to the concerned department for reacting against the problem.
- Localized phone: In almost all the sector a localized phone is present which can communicate with both CCR and the local region on the speaker. This may be used for warning or message.

## 4.4 Results and Discussions

### 4.4.1 Environmental Concerns of The Plant: -

To check the feasibility of the project environmental health along with the economics of the project is accounted for. The effect of C&D waste management facility on the environment is judged on the basis of air quality index, equivalent noise level, ground water pollution and ground pollution. Out of all the parameters the air quality is the most prominent factor to be considered as the air we breathe affects our health primarily. Secondarily comes the noise level that may impair our hearing ability. Also, here it is worthwhile to discuss the consequences of using a polymer as a flocculent on the properties of the soil when it is used by the customers either in the fields or in embankments.

**Air quality parameter: -**

- The sampling was done for 24 hrs. period continuously at the back side of office at IL&FS plant in burari.
- As per the CPCB's guidelines air quality testing should be done once in two months.
- The wind speed and ambient temperature was also noted down there, as with the increase in wind speed the amount of pollution load especially due to the particulate matter goes on increasing.
- Thus, higher values were obtained during high wind speed.

Table 10: Air Quality Parameters Of The Plant At Gate No-1

| S.no | Time period | $PM_{2.5}$(µg/m³) | | $PM_{10}$ (µg/m³) | | $SO_2$(µg/m³) | | $NO_2$(µg/m³) | |
|---|---|---|---|---|---|---|---|---|---|
| | | standard | actual | standard | actual | standard | actual | standard | actual |
| 1 | Feb.2016 | 60 | 39.50 | 100 | 80.23 | 80 | 28.62 | 80 | 34.58 |
| 2 | April.2016 | 60 | 41.34 | 100 | 85.28 | 80 | 25.02 | 80 | 36.25 |
| 3 | June 2016 | 60 | 44.93 | 100 | 83.65 | 80 | 20.31 | 80 | 31.53 |
| 4 | Sep.2016 | 60 | 46.28 | 100 | 83.56 | 80 | 12.08 | 80 | 35.33 |
| 5 | Nov.2016 | 60 | 172.60 | 100 | 528.9 | 80 | 26.7 | 80 | 59.3 |
| 6 | Feb.2017 | 60 | 57.46 | 100 | 88.21 | 80 | 13.19 | 80 | 28.56 |
| 7 | April 2017 | 60 | 69.1 | 100 | 110.25 | 80 | 11.21 | 80 | 21.09 |

**Equivalent noise level: -**

- To check the sound level at the plant due to the processing facility, the sound level meter is used.
- The sampling was done at the Gate No. 1 of the plant both during the day and night time and it should be done once in three months as per the guidelines of CPCB.
- $L_{eq}$ denotes the time weighted average of level of sound in decibels with reference to a scale that can be related to the human hearing.
- The noted down reading are compared to the standards prescribed by the concerned authority.

Table 11: Equivalent noise level at plant's Gate no-1

| **S.no** | **Time period** | **$L_{eq}$ (dB) Day** | | **$L_{eq}$ (dB) Night** | |
|---|---|---|---|---|---|
| | | standard | actual | standard | actual |
| **1** | March.2016 | 55 | 74.21 | 45 | 67.43 |
| **2** | June.2016 | 55 | 73.56 | 45 | 65.59 |
| **3** | Oct. 2016 | 55 | 73.83 | 45 | 68.36 |
| **4** | Feb.2016 | 55 | 68.48 | 45 | 59.77 |

**Soil Pollution: -**

Polyacrylamide is used as a coagulant in the flocculation process for removing the Suspended Soil from the water at the IL&FS plant. PAM is a polymer of acrylamide monomer and is a water soluble synthetic compound making it a choice for use as a coagulant in removing the sediments from the storm water at construction sites. Its molecular weight can range from $10^5$ g/mol to $5\times 10^6$ g/mol and can be in any form based on the copolymerization process like anionic, cationic or non ionic. The cationic form is used for flocculation of sewage sludge and various industrial wastes thus rendering it as a soil stabilizers. It prevents the formation of surface seal and increases the infiltration of the water applied to the soil during rains or irrigation. Studies have proven that PAM can be effectively used in fields as a soil stabilizer when used in furrow or sprinkler method of irrigation.

Although we have a number of environmental concerns with the use of PAM as its toxicity depends upon the charge carried by the molecule and the type of molecule i.e anionic or cationic. On reaching the soil it is liable to be degraded by the various agencies like cultivation, mechanical breakage of soil, chemical hydrolysis, effects of light and temperature etc but the it degrades at a slow rate of 10% per year (Barvenik, 1994). It is nontoxic to humans but can cause skin and eyes irritation and itching on exposure to it. The accumulation of PAM in environment is a real concern but still this is a topic of debate as per different findings by number of researchers. Some of the highlights of the case study at IL&FS plant using the PAM is discussed here below:-

- Polymer used in the process of flocculation is the primary source of soil pollution.
- After the formation of cakes in the filter press the soil is left for drying but it contains the effects of polymer in it.
- Now when this soil is used for embanking or in farms, the presence of polyacrylamide can interfere with the purposed working.
- On testing the soil in context of its properties like water holding capacity, shear strength etc, it is found that the capacity of soil to retain the water has improved because of the complex structure of polymer as it fixes the water molecules in its branches.

### 4.4.2. Economics of project: -

Economy of any project depends upon the difference of the revenue generated and the expenses made in a financial year. The complete details of all the expenses and revenue is maintained in a prescribed format via balance sheet. All the companies and firms have to maintain their balance sheet every financial year which is the responsibility of the accounts department.

At IL&FS revenues are generated in the form of tipping fees, selling of concrete bricks, paver blocks, kerb stones, and selling the recycled aggregates of different sizes.

Whereas the expenses incurred at the IL&FS plant are in the form of Processing of C&D waste, Salary of employs, Maintenance of machinery, Fuel charges and machine operating cost, Electricity charges and etc

### Revenue generation: -

The main source of revenue generation for the plant is by selling the products obtained from the recycling of C&D waste in the market. Out of 2000 ton processed, wet process contributes in treating around 1600 ton. The products of the wet process are mainly sand, silt, and granular sub base (GSB) and have the following composition sand 17%; GSB (<20mm) 30%; GSB (>20mm)

15%; and Silt 38%. Whereas the remaining 400 ton is processed by the dry process and the products obtained with respective percentages are stone dust 15%; 10mm stone aggregates 28%; 20mm stone aggregates 28%; and soil 29%. These items along with the finished products like paver blocks, concrete bricks etc.

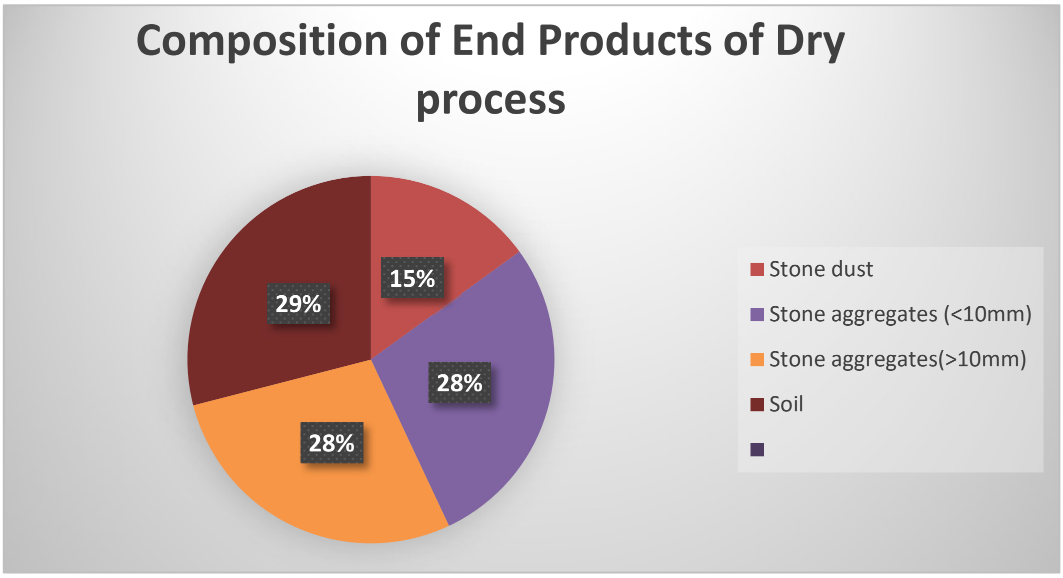


Figure 23: Composition of end products from dry process

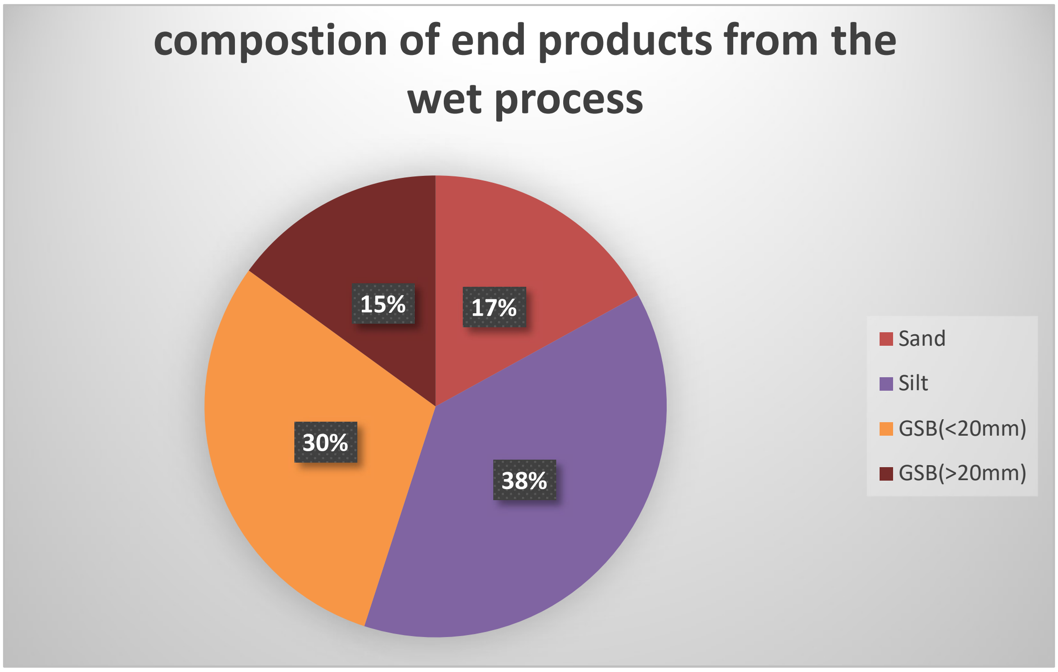


Figure 24: Composition of end products from the wet process

On the basis of the table no.13 and composition of end products obtained from both the dry and wet processes as shown in figures 26 and figure 27, the total revenue generated is worked upon. The prices of respective material are provided by the accounts department of the plant and is used in calculating the revenues generated. The total amount raised by the plant on daily basis is **INR 10,62,140.**

Table 12: Revenue generation (Accounts department of IL&FS plant)

| S.no | Item | Price (Rs/Ton) | Quantity of products (TPD) | Revenue generated in INR |
|---|---|---|---|---|
| 1 | Tipping fee | 205 | 2000 | 4,10,000 |
| 2 | Stone dust | 657 | 60 | 39,420 |
| 3 | Stone aggregate 20mm | 650 | 112 | 72,800 |
| 4 | Stone aggregate 10mm | 690 | 112 | 77,280 |
| 5 | Brick mix aggregate (GSB) 10mm and 20mm | 542 | 720 | 3,90,240 |
| 6 | Mud dry | 100 | 724 | 72,400 |
| | | | Total revenue generated= 10,62,140 | |

## Expenses made: -

During the processing of C&D waste for achieving the daily target of 2000TPD, plant is made to run continuously for 24 hours and this in turn requires manpower as well as source of power and many other miscellaneous expenditures like that on maintenance and repairing work. So, to carry out all the activities the most important thing is the capital.

- The cost of scientific land filling is approximately **Rs.650 per Ton.**
- **The total cost** to company for processing of C&D waste is **Rs.490 per ton** as per the sources of the company and thus amounting to **INR 9,80,000 per day**
- From the above data, it is clear that recycling is far more better than landfilling economically as well as environmentally because till now the 28 Lakh Million Tons of C&D waste has been efficiently processed by the plant.
- Whereas the total revenue raised by the plant on selling the products is **INR 10,62,140 per day.**

- Thus, the net income of the plant is **INR 82,140 per day** thus making it a "*For profit*" entity working for the environment.

#### 4.4.3 Products meets the buyers: -

One similar approach for recycling the C&D waste was followed by YUVA and CIDCO in Navi Mumbai as they recycled around 1500-1600 ton of C&D waste between 2002 to 2006 but due to the lack of standards and support by the govt. the products were unable to get any attention and buyers. So, keeping in mind the IL&FS brought out the technique with a stronger back hold of results obtained from the testing and the comparison of results with that of natural virgin material. The products obtained from the waste are subjected to a no of tests like impact test, abrasion test, sieve analysis, water holding capacity, compressive strength etc and only after the confirmation they are put to market for sale. So far, the products of the C&D plant have found applicability in a no of projects like:

- 8-9 lakh tons of aggregates has been supplied to **Delhi Development Authority (DDA)** for making a 10-km trial road strip in the South Delhi's Bakkarwala region.
- On the basis of the concept of Green Building, 15 lakh concrete bricks have been supplied to the JMC for building a new complex of **Supreme Court of India** on a 12.19 acre of land adjoining the Pragati Maidan. It will be used in boundary walls and in inner walls up to a height of 5 feet. This product is selected for its better durability and dead weight as compared to fly ash bricks.
- For construction of **western court Annex at Jan path** Delhi, 1 lakh concrete bricks have been used so far. The project aims at building 88 transit suites for the Members of Parliament at an expected cost of INR 49 crores.
- Besides this concrete brick have the applicability in the mountainous regions as a substitute to the wooden houses because of the availability of aggregates in bulk there.
- Also, the aggregates can be used by the local contractors for the construction projects of any type.
- **NDMC** uses the recycled paver blocks, kerb stones, chequered tiles and interlocking tiles for all its road side works.

# CONCLUSION

In the past decade construction industry in India witnessed a drastic growth due to the increased investment in the real estate and building sector which is a consequence of shooting requirement of housing induced due to the rapid migration of people toward urban areas and secondly due to the flow of money in the economy of India. This pace will further accelerate as the projects regarding the smart cities are still in queue to become a reality. The complexity in finding a standard solution for C&D waste is the uncertainties and anomalies in its definition and it also varies according to type and location of the project executed. Dumping of wastes on land is the main reason for the shrinking urban areas. Therefore, it is the need of hour to go for recycling and re-use of demolition and concrete waste to save environment, cost and energy.

On analyzing all the waste management techniques, the circular economy model emerges as the most viable due to several reasons. The currents case study of IL&FS plant is based on recycling as the only option without considering the value for material. The Circular Economy whereas focuses on the value restoration and value creation by applying the concept of 4R in a long run. For successfully application of the CE concept and to shift from the linear economy, a rethinking of patterns in view of designs of products and processes is required. The approach of C2C and LCA techniques is not clear in its mandate of minimization of waste with restoration of value.

When talking about the C2C concept and the nutrients envisaged in it, scope of C&D waste management is not clear here. The biological nutrient in C&D waste is only soil and wood that can go to biological cycle but the contribution of wood and soil is very scarce in the C&D waste stream. Concrete is biodegradable up to the point water is not mixed in it and bricks can biodegrade only by the erosion process which is very slow one. Thus, the main composition can't also be considered as biological nutrients. Majority of C&D waste comes from the residential and infrastructural projects where ownership is not retained by the contractors after handling over to the buyers mostly. Thus, it is also complicated to view C&D waste from the angle of offering a service with the ownership remaining with one person and hence it can't be classified as the technical nutrient defined in the C2C system.

Although we have the knowledge of all the waste minimization techniques like C2C, LCA and CE in India but we still are limited to the option of recycling as indicated by the case study of IL&FS plant but it still gives some condolence as since its inception in 2009, the plant has processed around 28 lakhs ton of C&D waste till Dec.2016 and still is going to tackle the problem at a very fast rate of 2000 TPD. Also, due to the shortage of land in cities like Delhi, the problem is getting worsen with the its rapidly developing status. So, keeping in mind about the waste three prime zones of north Delhi were first selected- Saddar Paharganj, Karol Bagh, City zone- but later it was proposed to cover other zones of north MCD like Narela zone, Rohini zone etc. Now almost all the areas of North MCD is being covered by the facility and the dumping of waste is carried out either by the NDMC or by any other agency and for dumping only there exists a tipping fee of Rs205 /ton of waste and it acts as a source of income to the IL&FS along with the solution to the waste generator.

It was a topic of argument that the facility will lead to air laden pollution in the form of suspended particulate matter like $PM_{2.5}$ and $PM_{10}$, but the testing of the air quality parameters periodically i.e once in two months proves that almost all through the year except the summers with high wind speed, the air quality parameters remains well below the NAAQS.

Yes, it is the equivalent noise level that is exceeding the limits as it can be attributed to the machines operating 24*7 hours but with the green belt and the sound barrier at the periphery of plant this noise level can be managed.

As far as the **economy and feasibility** of the plant is concerned, I can say that IL&FS and the environment both are benefitting and this entity and project is an ideal to the society and other entities as this will boom the innovation of extracting the gold from waste and this will lead to decrease in the pressure on the mining of virgin earth material. On similar lines of this project, some new plants have already been started and some are in proposal to start, like a new facility at MUNDKA in collaboration with DMRC will have the facility of treating 300 TPD of waste. But all it requires is the formulation of standards by BIS that allows the efficient and effective use of the recycled products.

The current scenario of the Indian C&D waste processing industry is attributed to a no of factors that has blocked the way for waste management facility. Till now no research was conducted and no accurate data was available with the ministries and the govt. Following are some of the reasons for such pity condition of industry: -

- No legal frame work: -MSW (management and handling rules) 2000 had only a brief mention of C&D rules in some pages without having any guidelines for its management.
- The BIS allows use of non-natural materials to be used for construction but doesn’t account the recycled material in this category of non-natural material, that causes a big turmoil among various agencies and shareholders.
- Most of the agencies are abstaining from using recycled waste citing Indian standard specification related to aggregates for using only virgin material.

- Excuses are made by the generators and industries regarding the recycling of waste like it will slow down the job; no space available for onsite recycling; it costs too much; it is out of the terms of contracts etc.
- Although C&D waste management rules 2016 are introduced for the first time but it fails to propose a plan to tackle the problem efficiently as it only discusses the duties of various stakeholders in this respect and the criteria for selecting the location of C&D waste recycling facility and the time framework to comply with the rules. These rules are attached in Annexure 2.

India needs a strong policy to protect its land, public space and ecology from the shooting construction industry that is expected to explode with the urban boom. There is no option of delaying the policy implementation left with us as far as environment and ecology is concerned. In this regard following steps should be taken: -

- **Formation of BIS codes permitting the use of recycled material**: An example in this regard has already been set by introducing the exceptions clause for fly ash use. So, the same can be done again on the basis of compliance results of products from the C&D waste.
- **Revision of Schedule of rates by CPWD:** on the basis of research data done by leading Indian institutes like CRRI and NCCBM, the schedule of rates should be revised to include the recycled product in the mainstream. This will ensure a market for the recycled products and thus making it a viable option.
- **Introduce tax system on landfilling:** dumping of the waste in landfills or in open air should come under the taxation system as done by the Denmark Govt. and as a result the landfill level in EU countries decreased from 39% to 6%.
- **Promote the concept of Circular Economy:** it should be implemented only from the planning phase of the material to design intentionally for products value restoration.
- **Making the ULB's and state govt. as the stake holder:** we have to confer responsibilities and power to the state govt. and its allied ULB's to make estimates of the waste generated, to provide disposal and recycling facilities proactively.
- **Making the PPP and EPR models working:** for attributing and deciding the responsibility of producers and manufacturers models like polluter pays principle (PPP) and extended producer responsibility (EPR) should be followed and implemented to minimize the waste generation.
- **Detailed waste management plan:** only defining duties to stakeholders and scheduling site selection criteria won't work in reducing the waste as mentioned in "C&D waste

management rules 2016" rather a detailed plan that cover the whole industry should be drafted starting from the planning phase and covering all the lifecycle steps of the material.

- **Learning internationally:** In India, we should learn from the international experiences in the field of waste management and waste minimization like the pioneering work by European union countries-Netherlands, Denmark, Norway-etc; USA; Japan; Hong Kong; South Korea; Singapore; Malaysia.

IL&FS Environmental infrastructure & service limited has a large role in developing the country, there exists a high demand for such type of recycling facility so that the increasing burden on the land for the disposal of C&D waste can be minimized effectively.

# REFRENCES


Al-Mutairi, N. and Haque, M. (2003) "Strength and Durability of Concrete Made with Crushed Concrete as Coarse Aggregates". Proceedings of the International Symposium on Recycling and Reuse of Waste Materials, Scotland, September 2003, 499-506.

Ansary, M.S., El-Haggar, S.M. and Taha, M.A. (2004) "Sustainable Guidelines for Managing Demolition Waste in Egypt", 9-11 Nov. 2004, Barcelona, Spain.

Bansal ,S., Singh, S.K.,(2014) "A Sustainable Approach Towards the C&D Waste", IJIRSET vol.3, issue2, Febraury 2014.

Bansal, S., Singh, S.K., (2015), " Sustainable Handling of C&D Waste", International Journal of Sustainable Energy And Environmental Research, 2015 4(2), 22-48.

Barvenik, F.W. (1994), "PAM Characterstics Related to Soil Application" Soil Science, vol.158 , 235-243.

Braungart, M. & McDonough, W.,2002. *Cradle to cradle: remaking the way we make things* 1st ed., Jonathan Cape London.

Braungart, M. & McDonough, W.,2008. *Cradle to cradle: remaking the way we make things* 2nd ed., Jonathan Cape London.

Central Pollution Control Board Report (2012), "Status Report on Municipal Solid Waste Management".

Chini, A.R., Goyal, N. (2012), " Maximizing Reuse and Recycling of Construction Material" 48th ASC Annual International Conference Proceeding

Chun-Li, P., Grosskopf, K.R. and Kibert, C.J. (1994) "Construction Waste Management and Recycling Strategies in the United States". Proceedings of the First Conference of CIB TG 16 on Sustainable Construction, Tampa, 689-696.

Elgizawy, S.M., El-Haggar, S.M., Nassar, K. (2016), "Approaching Sustainability of Construction and DemolitionWaste Using Zero Waste Concept" Low Carbon Economy 2016, 7, 1-11.

El Haggar, S. (2007),"Sustainable Industrial Design and Waste Management: Cradle-To-Cradle for Sustainable Development" Academic Press, Cambridge, Massachusetts.

Ellen MacArthur Foundation, 2012. *Towards The Circular Economy*, Ellen MacArthur Foundation.

Ellen MacArthur Foundation, 2013. *Towards The Circular Economy*, Ellen MacArthur Foundation.

European Commission (EU) (2000), Management of construction and demolition wastes: working document no. 1, directorate-general environment, waste management.

European Commission, 2011. Taxes on Natural Resources Reduce Use of Raw Materials.

European Commission, 2012. EU Waste Policy. The story behind Strategy., European Commission

European Commission, 2013. EU Green Public Procurement Policy., pp.1-7.

European Commission,1991. Directive on Hazardous waste.

Gavilan, R.M. and Bernold, L.E (1994), “Source Evaluation of Solid Waste in Building construction”, Journal of Construction Engineering and Management, ASCE 120(3), 536-552.

Gayakwad, H.P., Sasane, N.B.,(2015) construction and demolition waste management in India, IRJET vol.2

Grubl, P and Ruhl, M., (1998), Concrete with recycled aggregates, International Symposium on Sustainable construction: Use of Recycled Concrete Aggregate, 11-12th Nov. 1998, University of Dundee, London

(Uk)

Hansen, E., 2004. *Life cycle assessment of land filled waste,* Copenhagen; Environmental protection agency.

Hauschild, M. et al., 2008. *Gone ..... But not away- addressing the problem of long term impacts from landfills in LCA.* The International journal of Life Cycle Assessment, 547-554.

Hendriks, C.F. and Pietersen, H.S. (2000), Sustainable raw materials: Construction and Demolition waste. RILEM Publication, Cachan Cedex, France

http://mospi.nic.in/data

http://statisticstimes.com/economy/gdp-capita-of-india.php

http://statisticstimes.com/economy/sectorwise-gdp-growth-of-india.php

http://tifac.org.in/index.php?option=com_content&id=710&Itemid=205

http://www.tifac.org.in/index.php?option=com_content&view=article&id=710&Itemid=205 ,retrieved on 24th June 2013

http://zeenews.india.com/news/nation/additional-building-for-supreme-court-to-be-constructed_785462.html

https://en.wikipedia.org/wiki/Cradle-to cradle_design#/media/File:Sustainability_methods_featuring_C2C.png

https://en.wikipedia.org/wiki/International_Organization_for_Standardization

https://en.wikipedia.org/wiki/Life-cycle_assessment

https://upload.wikimedia.org/wikipedia/commons/0/09/Life_Cycle_Assessment_Overview.jpg

https://www.nbmcw.com/construction-infra-industry/1835-construction-sector-current-scenario-and-emerging-trends.html

https://www.youtube.com/watch?v=DYGQGygGwG8

IL&FS (2014) “Standard operating procedure for C&D waste recycling plant “ at Burari.

Jarman, D.S. (1996), “Developing a Cost Effective Construction and Demolition Waste Management Plan” Virginia Polytechnic Institute and State University.

Kareem, K.R., Pandey, R.K, (2008), “Study of Management and Control of Waste Construction Materials in Civil Construction Project,” IJRET: International Journal of Research in Engineering and Technology

Kibert , C., (1994). *Sustainable construction,* Florida: University of Florida.

Kim, J.-J. (1998) Sustainable Architecture Module: Qualities, Use, and Examples of Sustainable Building Materials College of Architecture and Urban Planning, The University of Michigan, Ann Arbor.

Kumbhar, S.A., Gupta, A.K., Desai, D.B.(2013), “Recycling and Reuse of Construction and demolition Waste for Sustainable Development” OIDA International Journal of Sustainable Development 06:07 (2013)

Lauritzen, E.K. and Hahn, N.J. (1992) Building Waste-Generation and Recycling. ISWA.

Masudi, A.F., Mahmood, N.Z., Sulaiman, N.M. (2012), “Waste quantification models for estimation of construction and demolition waste generation: a review” Int. J. Global Environmental Issues, Vol. 12, Nos. 2/3/4, 2012

Meyer, K.S. and Walsh, J.J. (1996) Rags among the Ruins. Wastes 360 Recycling Summit, 20-23. http://waste360.com/mag/waste_regs_among_ruins

Mullick, A.K. (2014), “Management of Construction and Demolition Waste- Current Status,” Indian Building Congress.

Mora, E. P. (2007), Life cycle, sustainability and the transcendent quality of building materials, Building and Environment, 42, 1329-1334.

Napier, T. (2012),. Construction Waste Management. U.S. Army Corps of Engineers, Engineer Research and Development Center / Construction Engineering Research Laboratory.

Patel, S., Pansuria, A., Shah, V and Patel, S. (2014), “Construction and Demolition Waste Recycling”, IJIRST –International Journal for Innovative Research in Science & Technology Volume 1, Issue 7, December 2014

Papadopoulos, A., Fatta, D., Avramikos, E., Sgourou, E., Moustakas, K., Kourmoussis, F., Mentzis, A. and Loizidou, M. (2003) “Generation and Management of Construction and Demolition Waste in Greece—An Existing Challenge.” Resources Conservation and Recycling Journal, 40, 81-9.

Ponnada, M.R., Kameswari, P. (2015), “Construction and Demolition Waste Management – A Review” International Journal of Advanced Science and Technology, vol.84 ,19-46.

Riggie, D. (1992), “Diverting Commercial Building Materials” Biocycle 54-55

Satendra, Anandha, K.J,. Naik, A.K. (2014), “India Disaster Report 2013”, National Institute of Disaster Management.

Shetty, M.S.,( 2011) “CONCRETE TECHNOLOGY”, 93-114.

Shetty, R.S., (2013) “construction and demolition waste -An overview of construction Industry in India”, IJCEBS vol.1, issue 4

Skoyles, E.R. (1976b) “Waste of Materials and the Contractors Quantity Surveyor”. The Quantity Surveyor, 209-211.

Skoyles, E.R., (1976) “Materials Waste—A Misuse of Resources”. Batiment International, Building Research and Practice, 4, 232.

Soni, K.M., (2014), “Avoidance of Waste Generation for Construction and Demolition Waste Management,” Indian Building Congress.

Spivey, D.A. (1974) Environmental and Construction Management Engineers. Journal of Construction, 100, 395-401.

Symonds group Ltd., ARGUS, COWI., Bouwcentrum PRC., (1999) “Construction and Demolition Waste Management Practices, and Their Economic Impacts”. Report to DGXI, European Commission.

Tchobanoglous, G., Theisen, H. and Eliassen, R. (1977) “Solid Wastes: Engineering Principles and Management Issues”. McGraw-Hill Book Co., New York.

Technology Information, Forecasting and assessment Council, Dept. Science and Technology, Government of India. (Table: Quantity and make up of C&D Waste)

Technology Information, Forecasting and Assessment Council-Department of Science and Technology, Government of India (http://www.tifac.org.in/index.php?option=com_content&view=article&id=710&Itemid=205)

Thomas, J., Wilson P. M., (2008 ) “Construction Waste Management in India,” Journal of Environmental Research And Development Vol. 2 No.4

Thormark, C., (2001). “Conservation of Energy and Natural Resources by recycling building waste”. Resources, Conservation and Recycling, 33, 113-130.

Torgal, F.P. and Labrincha, J.A. (2013) “The Future of Construction Materials Research and the Seventh UN Millennium Development Goal: A Few Insights”. Journal of Construction and Building Materials, 40, 729-737

Vaishali, A., Geeta, N., Kanachan, A., and Patel, N., (2012), “Construction and Demolition Waste management- Case Study of Pune” Twenty Eight National Convention of Civil Engineers and National Seminar.

World Bank Report (2012), “WHAT A WASTE A Global Review of Solid Waste Management”.

World Business Council for Sustainable Development (WBCSD, 2009), Concrete recycling: the cement sustainability initiative.

www.ciwmb.ca.gov/ConDemo/Specs/ Source/author: California Integrated Waste Management Board.

www.wbdg.org/design/index. php? cn=4.3.4&cx=0 Source/Author: Whole Building Design Guide.

www.epa.gov/rtp/new-bldg/environmental/s_01690.htm Source/author: U.S. Environmental Protection Agency.

www.stopwaste.org/fsbuild.html Source/author: Alameda County Waste Management Authority.

www.tjcog.dst.nc.us/cdwaste.htm#wastespec Source/author: Triangle J Council of Governments (NC).

www.urbanindia.nic.in

www.waste-management-world.com

ZWIA, Zero Waste International Alliance (2013) ZW Definition. http://zwia.org/standards/zw-definition/

# APPENDICES

## Appendix 1:

Rate List of Recycled C&D Waste Products

| S.no | Item Name | Units | DSR 2016 | Recycled product |
|---|---|---|---|---|
| 1 | Stone dust | $m^3$ | 865 | 1150 |
| 2 | Brick Mix aggregate 40mm | $m^3$ | 750 | 670 |
| 3 | Stone aggregate 20mm | $m^3$ | 1300 | 1105 |
| 4 | Stone aggregate 10mm | $m^3$ | 1300 | 1105 |
| 5 | Surkhi | $m^3$ | 700 | 720 |
| 6 | Precast CC kerb stone | $m^3$ | 3800 | 4750 |
| 7 | Mud dry | $m^3$ | 150 | 120 |
| 8 | Cheq. Tile cement concrete(22mm) | $m^2$ | 235 | 195 |
| 9 | Cheq. Tile with 50 % white cement | $m^2$ | 350 | 295 |
| 10 | Paver and tile -grey colour | $m^2$ | 350 | 340 |
| 11 | Paver and tile -red colour | $m^2$ | 500 | 390 |
| 12 | Paver and tile -yellow colour | $m^2$ | 500 | 430 |
| 13 | Brick mix aggregates 10mm | $m^3$ | - | 705 |
| 14 | Brick mix aggregate 20mm | $m^3$ | - | 705 |
| 15 | Concrete brick(400*200*100 mm) | $m^3$ | 2750 | 3635 |

*IL&FS plant Burari, Delhi*

# Appendix 2:
## The Construction and Demolition Waste Management Rules 2016.

**[Published In the Gazette of India, Part-II, Section-3, Sub-section (ii)]**
**Ministry of Environment, Forest and Climate Change**

**NOTIFICATION**

**New Delhi, the 29th March, 2016**

**G.S.R. 317(E).-**Whereas the Municipal Solid Wastes (Management and Handling) Rules, 2000 published vide notification number S.O. 908(E), dated the 25th September, 2000 by the Government of India in the erstwhile Ministry of Environment and Forests, provided a regulatory frame work for management of Municipal Solid Waste generated in the urban area of the country;

And whereas, to make these rules more effective and to improve the collection, segregation, recycling, treatment and disposal of solid waste in an environmentally sound manner, the Central Government reviewed the existing rules and it was considered necessary to revise the existing rules with a emphasis on the roles and accountability of waste generators and various stakeholders, give thrust to segregation, recovery, reuse, recycle at source, address in detail the management of construction and demolition waste.

And whereas, the draft rules, namely, the Solid Waste Management Rules, 2015 with a separate chapter on construction and demolition waste were published by the Central Government in the Ministry of Environment, Forest and Climate Change vide G.S.R. 451 (E), datedthe 3rd June, 2015 inviting objections or suggestions from the public within sixty days from the date of publication of the said notification;

And Whereas, the objections or suggestions received within the stipulated period were duly considered by the Central Government;

Now, therefore, in exercise of the powers conferred by sections 6, 25 of the Environment (Protection) Act, 1986 (29 of 1986), and in supersession of the Municipal Solid Wastes (Management and Handling) Rules, 2000, except as respect things done or omitted to be done before such supersession, the Central Government hereby notifies the following rules for Management of Construction and Demolition Waste –

**1. Short title and commencement.-**(1) These rules shall be called the Construction and Demolition Waste Management Rules, 2016.

(2) They shall come into force on the date of their publication in the Official Gazette.

**2. Application.-**The rules shall apply to every waste resulting from construction, re-modeling, repair and demolition of any civil structure of individual or organisation or authority who generates construction and demolition waste such as building materials, debris, rubble.

**3.** **Definitions –**(1) In these rules, unless the context otherwise requires,-

(a) " ACT' means the Environment ( Protection) Act, 1986 (29 of 1986);

(b) "**construction**" means the process of erecting of building or built facility or other structure, orbuilding of infrastructure including alteration in these entities,;

(c) "**construction and demolition waste**" means the waste comprising of building materials, debris and rubble resulting from construction, re-modeling, repair and demolition of any civil structure;

(d) **"de-construction"** means a planned selective demolition in which salvage, re-use and recycling of the demolished structure is maximized;

**(e)** **"demolition"** means breaking down or tearing down buildings and other structures either manually or using mechanical force (by various equipment) or by implosion using explosives.

**(f)** **"form" means a Form annexed to these rules;**

**(g)** **"local authority"** means an urban local authority with different nomenclature such as municipal corporation, municipality, nagarpalika, nagarnigam, nagarpanchayat, municipal council including notified area committee and not limited to or any other local authority constituted under the relevant statutes such as gram panchayat, where the management of construction and demolition waste is entrusted to such agency;

**(h)** **" schedule"** means a schedule annexed to these rules;

**(i)** **"service provider'** means authorities who provide services like water, sewerage, electricity, telephone, roads, drainage etc. often generate construction and demolition waste during their activities, which includes excavation, demolition and civil work;

**(j)** **"waste generator" means any person or association of persons** or institution, residential and commercial establishments including Indian Railways, Airport, Port and Harbour and Defence establishments who undertakes construction of or demolition of any civil structure which generate construction and demolition waste.

(2) Words and expressions used but not defined herein shall have the same meaning defined in the ACT.

**(4)** **Duties of the waste generator -**

(1) Every waste generator shall prima-facie be responsible for collection, segregation of concrete, soil and others and storage of construction and demolition waste generated, as directed or notified by the concerned local authority in consonance with these rules.

(2) The generator shall ensure that other waste (such as solid waste) does not get mixed with this waste and is stored and disposed separately.

(3) Waste generators who generate more than 20 tons or more in one day or 300 tons per project in a month shall segregate the waste into four streams such as concrete, soil, steel, wood and plastics, bricks and mortar and shall submit waste management plan and get appropriate approvals from the local authority before starting construction or demolition or remodeling work and keep the concernedauthorities informed regarding the relevant activities from the planning stage to the implementation stage and this should be on project to project basis.

(4) Every waste generator shall keep the construction and demolition waste within the premise or get the waste deposited at collection centre so made by the local body or handover it to the authorised processing facilities of construction and demolition waste; and ensure that there is no littering or deposition of construction and demolition waste so as to prevent obstruction to the traffic or the public or drains.

(5) Every waste generator shall pay relevant charges for collection, transportation, processing and disposal as notified by the concerned authorities; Waste generators who generate more than 20 tons or more in one day or 300 tons per project in a month shall have to pay for the processing and disposal of construction and demolition waste generated by them, apart from the payment for storage, collection and transportation. The rate shall be fixed by the concerned local authority or any other authority designated by the State Government.

**(5) Duties of service provider and their contractors -**

(1) The service providers shall prepare within six months from the date of notification of these rules, a comprehensive waste management plan covering segregation, storage, collection, reuse, recycling, transportation and disposal of construction and demolition waste generated within their jurisdiction.

(2) The service providers shall remove all construction and demolition waste and clean the area every day, if possible, or depending upon the duration of the work, the quantity and type of waste generated, appropriate storage and collection, a reasonable timeframe shall be worked out in consultation with the concerned local authority.

(3) In case of the service providers have no logistics support to carry out the work specified in sub-rules (1) and (2) , they shall tie up with the authorised agencies for removal of construction and demolition waste and pay the relevant charges as notified by the local authority.

**(6) Duties of local authority-**The local authority shall,-

(1) issue detailed directions with regard to proper management of construction and demolition waste within its jurisdiction in accordance with the provisions of these rules and the local authority shall seek detailed plan or undertaking as applicable, from generator of construction and demolition waste;

(2) chalk out stages, methodology and equipment, material involved in the overall activity and final clean up after completion of the construction and demolition ;

(3c) seek assistance from concerned authorities for safe disposal of construction and demolition waste contaminated with industrial hazardous or toxic material or nuclear waste if any;

(4) shall make arrangements and place appropriate containers for collection of waste and shall remove at regular intervals or when they are filled, either through own resources or by appointing private operators;
(5) shall get the collected waste transported to appropriate sites for processing and disposal either through own resources or by appointing private operators;

(6) shall give appropriate incentives to generator for salvaging, processing and or recycling preferably in-situ;

(7) shall examine and sanction the waste management plan of the generators within a period of one month or from the date of approval of building plan, whichever is earlier from the date of its submission;

(8) shall keep track of the generation of construction and demolition waste within its jurisdiction and establish a data base and update once in a year;

(9) shall device appropriate measures in consultation with expert institutions for management of construction and demolition waste generated including processing facility and for using the recycled products in the best possible manner;

(10) shall create a sustained system of information, education and communication for construction and demolition waste through collaboration with expert institutions and civil societies and also disseminate through their own website;

(11) shall make provision for giving incentives for use of material made out of construction and demolition waste in the construction activity including in non-structural concrete, paving blocks, lower layers of road pavements, colony and rural roads.

**(7) Criteria for storage, processing or recycling facilities for construction and demolition waste and application of construction and demolition waste and its products-**

(1) The site for storage and processing or recycling facilities for construction and demolition waste shall be selected as per the criteria given in **Schedule I**;

(2) The operator of the facility as specified in sub- rules (1) shall apply in **Form I** for authorization from State Pollution Control Board or Pollution Control Committee.

(3) The operator of the facility shall submit the annual report to the State Pollution Control Board in **Form II.**

(3) Application of materials made from construction and demolition waste in operation of sanitary landfill shall be as per the criteria given in **Schedule II.**

**(8) Duties of State Pollution Control Board or Pollution Control Committee-**

(1) State Pollution Control Board or Pollution Control Committee shall monitor the implementation of these rules by the concerned local bodies and the competent authorities and the annual report shall be sent to the Central Pollution Control Board and the State Government or Union Territory or any other State level nodal agency identified by the State Government or Union Territory administration for generating State level comprehensive data. Such reports shall also contain the comments and suggestions

of the State Pollution Control Board or Pollution Control Committee with respect to any comments or changes required;

(2) State Pollution Control Board or Pollution Control Committee shall grant authorization to construction and demolition waste processing facility in **Form-III** as specified under these rules after examining the application received in **Form I**;

(3) State Pollution Control Board or Pollution Control Committee shall prepare annual report in **Form IV** with special emphasis on the implementation status of compliance of these rules and forward report to Central Pollution Control Board before the 31$^{st}$July for each financial year.

**(9) Duties of State Government or Union Territory Administration-**

(1) The Secretary in-charge of development in the State Government or Union territory administration shall prepare their policy document with respect to management of construction and demolition of waste in accordance with the provisions of these rules within one year from date of final notification of these rules.

(2) The concerned department in the State Government dealing with land shall be responsible for providing suitable sites for setting up of the storage, processing and recycling facilities for construction and demolition waste.

(3) The Town and Country planning Department shall incorporate the site in the approved land use plan so that there is no disturbance to the processing facility on a long term basis.

(4) Procurement of materials made from construction and demolition waste shall be made mandatory to a certain percentage (say 10-20%) in municipal and Government contracts subject to strict quality control.

**(10) Duties of the Central Pollution Control Board -** (1) The Central Pollution Control Board shall,-

(a) prepare operational guidelines related to environmental management of construction and demolition waste management;

(b) analyze and collate the data received from the State Pollution Control Boards or Pollution Control Committee to review these rules from time to time;

(c) coordinate with all the State Pollution Control Board and Pollution Control Committees for any matter related to development of environmental standards;

(d) forward annual compliance report to Central Government before the 30$^{th}$August for each financial year based on reports given by State Pollution Control Boards of Pollution Control Committees.

**(11) Duties of Bureau of Indian Standards and Indian Roads Congress -**The Bureau of Indian Standards and Indian Roads Congress shall be responsible for preparation of code of practices and standards for use of recycled materials and products of construction and demolition waste in respect of construction activities and the role of Indian Road Congress shall be specific to the standards and practices pertaining to construction of roads.

**(12) Duties of the Central Government -**

(1) The Ministry of Urban Development, and the Ministry of Rural Development, Ministry of Panchayat Raj, shall be responsible for facilitating local bodies in compliance of these rules;

(2) The Ministry of Environment, Forest and Climate Change shall be responsible for reviewing implementation of these rules as and when required.

**13. Timeframe for implementation of the provisions of these rules -**The timeline for implementation of these rules shall be as specified in **Schedule III:**

**14. Accident reporting by the construction and demolition waste processing facilities-**In case of any accident during construction and demolition waste processing or treatment or disposal facility, the officer in charge of the facility in the local authority or the operator of the facility shall report of the accident in **Form-V** to the local authority. Local body shall review and issue instruction if any, to the in-charge of the facility.

**Schedule I**

**Criteria for Site Selection for Storage and Processing or Recycling Facilities for construction and demolition Waste**

**[See Rule 7(1)]**

(1) The concerned department in the State Government dealing with land shall be responsible for providing suitable sites for setting up of the storage, processing and recycling facilities for construction and demolition and hand over the sites to the concerned local authority for development, operation and maintenance, which shall ultimately be given to the operators by Competent Authority and wherever above Authority is not available, shall lie with the concerned local authority.

(2) The Local authority shall co-ordinate (in consultation with Department of Urban Development of the State or the Union territory) with the concerned organizations for giving necessary approvals and clearances to the operators.

(3) Construction and demolition waste shall be utilized in sanitary landfill for municipal solid waste of the city or region as mentioned at Schedule I of thse rule. Residues from construction and demolition waste processing or recycling industries shall be land filled in the sanitary landfill for solid waste.

(4) The processing or recycling shall be large enough to last for 20-25 years (project based on-site recycling facilities).

(5) The processing or recycling site shall be away from habitation clusters, forest areas, water bodies, monuments, National Parks, Wetlands and places of important cultural, historical or religious interest.

(6) A buffer zone of no development shall be maintained around solid waste processing and disposal facility, exceeding five Tonnes per day of installed capacity. This will be maintained within thetotal area of the solid waste processing and disposal facility. The buffer zone shall be

prescribed on case to case basis by the local authority in consultation with concerned State Pollution Control Board.

(7) Processing or recycling site shall be fenced or hedged and provided with proper gate to monitor incoming vehicles or other modes of transportation.

(8) The approach and or internal roads shall be concreted or paved so as to avoid generation of dust particles due to vehicular movement and shall be so designed to ensure free movement of vehicles and other machinery.

(9) Provisions of weigh bridge to measure quantity of waste brought at landfill site, fire protection equipment and other facilities as may be required shall be provided.

(10) Utilities such as drinking water and sanitary facilities (preferably washing/bathing facilities for workers) and lighting arrangements for easy landfill operations during night hours shall be provided and Safety provisions including health inspections of workers at landfill sites shall be carried out made.

(11) In order to prevent pollution from processing or recycling operations, the following provisions shall be made, namely:

(a) Provision of storm water drains to prevent stagnation of surface water;
(b) Provision of paved or concreted surface in selected areas in the processing or recycling facility for minimizing dust and damage to the site.
(c) Prevention of noise pollution from processing and recycling plant:
(d) provision for treatment of effluent if any, to meet the discharge norms as per Environment (Protection) Rules, 1986.

(12) Work Zone air quality at the Processing or Recycling site and ambient air quality at the vicinity shall be monitored.

(13) The measurement of ambient noise shall be done at the interface of the facility with the surrounding area, i.e., at plant boundary.

(14) The following projects shall be exempted from the norms of pollution from dust and noise as mentioned above:

For construction work, where at least 80 percent construction and demolition waste is recycled or reused in-situ and sufficient buffer area is available to protect the surrounding habitation from any adverse impact.

(15) A vegetative boundary shall be made around Processing or Recycling plant or site to strengthen the buffer zone.

**Schedule II**

**Application of materials made from construction and demolition waste and its products.**

**[See Rule 7(3)]**

| Sl. No. | Parameters | Compliance Criteria |
|---|---|---|
| 1 | Drainage layer in leachate collection system at bottom of Sanitary Landfill Gas Collection Layer above the waste at top of Sanitary Landfill and<br>Drainage Layer in top Cover System above Gas Collection Layer of Sanitary Landfill<br>For capping of sanitary landfill or dumpsite, drainage layer at the top | Only crushed and graded hard material (stone concrete etc.) shall be used having coarse sand size graded material (2mm – 4.75mm standard sieve size).<br>Since the coarse sand particles will be angular in shape (and not rounded as for riverbed sand) protection layers of non-woven geo-textiles may be provided, wherever required, to prevent puncturing of adjacent layers or components. |
| 2 | Daily cover | Fines from construction and demolition processed waste having size up to 2 mm shall be used for daily cover over the fresh waste.<br><br>Use of construction and demolition fines as landfill cover shall be mandatory where such material is available. Fresh soil (sweet earth) shall not be used for such places and borrow-pits shall not be allowed. Exception – soil excavated during construction of the same landfill.<br>During hot windy days in summer months, some fugitive dust problems may arise. These can be minimised by mixing with local soil wherever available for limited period. |
| 3 | Civil construction in a sanitary landfill | Non-structural applications, such as kerb stones, drain covers, paving blocks in pedestrian areas. |

**Schedule III**
**Timeframe for Planning and Implementation**
**[See Rule 13]**

| Sl. No. | Compliance Criteria | Cities with population of 01 million and above | Cities with population of 0.5-01 million | Cities with population of less than 0.5 million |
|---|---|---|---|---|
| 1 | Formulation of policy by State Government | 12 months | 12 months | 12 months |
| 2 | Identification of sites for collection and processing facility | 18 months | 18 months | 18 months |
| 3 | Commissioning and implementation of the facility | 18 months | 24 months | 36 months |
| 4 | Monitoring by SPCBs | 3 times a year – once in 4 months | 2 times a year – once in 6 months | 2 times a year – once in 6 months |

***The time Schedule is effective from the date of notification of these rules.***

**FORM – I**
**See [Rule 7 (2)]**
**Application for obtaining authorisation**

To,
The Member Secretary

________________________Name of the local authority or Name of the agency :
appointed by the municipal authority

| | |
|---|---|
| Correspondence address<br>Telephone No.<br>Fax No. | |
| Nodal Officer and designation (Officer authorized by the competent authority or agency responsible for operation of processing or recycling or disposal facility) | |
| Authorisation applied for (Please tick mark) | Setting up of processing or recycling facility of construction and demolition waste |
| Detailed proposal of construction and demolition waste processing or recycling facility to include the following<br>Location of site approved and allotted by the Competent Authority.<br>Average quantity (in tons per day) and composition of construction and demolition waste to be handled | |

| | |
|---|---|
| at the specific site.<br>Details of construction and demolition waste processing or recycling technology to be used.<br>Quantity of construction and demolition waste to be processed per day.<br>Site clearance from Prescribed Authority.<br>Salient points of agreement between competent authority or local authority and operating agency (attach relevant document).<br>Plan for utilization of recycled product.<br>Expected amount of process rejects and plan for its disposal (e.g., sanitary landfill for solid waste).<br>Measures to be taken for prevention and control of environmental pollution.<br>Investment on project and expected returns.<br>Measures to be taken for safety of workers working in the processing or recycling plant.<br>Any preventive plan for accident during the collection, transportation and treatment including processing and recycling should be informed to the Competent Authority (Local Authority) or Prescribed Authority | |
| **Date:** | **Signature of Nodal Officer** |

**Form-II**

**See [Rule (7) (3)]**
**Format for Issue of Authorisation to the Operator**

File No.: ____________
Date : ______________

To,

____________________
____________________
____________________

**Ref : Your application number _________________________Dt. …………**

The ________________ State Pollution Control Board or Pollution Control Committee after examining the proposal hereby authorizes ________________ having their administrative office at _______________________________________ to set up and operate construction and demolition waste processing facility at__________________ on the terms and conditions (including the standards to comply) attached to this authorisation letter.

1. The validity of this authorisation is till ________________. After expiry of the validity period, renewal of authorisation is to be sought.

2. The ____________________ State Pollution Control Board or Pollution Control Committee may, at any time, for justifiable reason, revoke any of the conditions applicable under the authorisation and shall communicate the same in writing.

3. Any violation of the provision of the construction and demolition Waste Management Rules, 2016 shall attract the penal provision of the Environment (Protection) Act, 1986 (29 of 1986).

**Date:** **(Member Secretary)**
**Place:** **State Pollution Control Board/**
**Pollution Control Committee**

**Form –III See**

**[Rule 8(2) ]**

**Format of Annual Report to be submitted by Local Authority to the State Pollution Control Board**

(i) Name of the City or Town…………………….
(ii) Population…………………
(iii) Name and address of local authority or competent authority

Telephone No : ………………………………
Fax : ………………………………………….
Email ID: …………………………………….
Website: ……………………………………..

(iv) Name of In-charge or Nodal Officer dealing with construction and demolition wastes management with designation ………………………………………………

**1. Quantity and composition of construction and demolition waste including any deconstruction waste**

(a) Total quantity of construction and demolition waste generated during the whole year in metric ton

Any figures for lean period and peak period generation per day …………………..
Average generation of construction and demolition waste (TPD)
Total quantity of construction and demolition waste collected per day
Any Processing / Recycling Facility set up in the city ……………………………
Status of the facility

(b) Total quantity of construction and demolition waste processed / recycled (in metric ton)

Non-structural concrete aggregate :
Manufactured sand :
Ready-mix concrete (RMC) :
Paving blocks :
GSB :

Others, if any, please specify :

(c) Total quantity of Construction & Demolition waste disposed by land filling without processing (last option) or filling low lying areas

---

No of landfill sites used :
Area used :
Whether weigh-bridge facility used for quantity estimation? : Yes No

(d) Whether construction and demolition waste used in sanitary landfill (for solid waste) as per Schedule III : Yes No

**2. Storage facilities**

(a) Area orlocation or plot or societies covered for collection of Construction and Demolition waste

(b) No. of large Projects (including roadways project) covered

(c) Whether Area or location or plot or societies collection is Practiced (if yes, whether done by Competent Authority or Local Authority or through Private Agency or Non-Governmental Organization) :

(d) Storage Bins :

| | Specifications (Shape & Size) | Existing Number | Proposed for future |
|---|---|---|---|
| (i) Containers or receptacle (Capacity) : | | | |
| (ii) Others, please specify : | | | |

(e) Whether all storage bins/collection spots are attended for daily lifting : Yes No

(e) Whether lifting of Construction & Demolition Waste from Storage bins is manual or mechanical (please tick mark) please specify mode and equipment used : Manual Mechanical Others, (specify equipment)

**3. Transportation**

| | Existing Actually Required/Proposed number |
|---|---|
| Truck : | |
| Truck-Hydraulic : | |
| Tractor-Trailer : | |
| Dumper-placers : | |
| Tricycle : | |

Refuse-collector :
Others (Please specify) :

**4. Whether any proposal has been made to improve Construction and Demolition waste management practices**

**5. Have any efforts been made to involve PPP for processing of Construction & Demolition waste : If yes, what is (are) the technologies being used, such as:**

| Processing / recycling Technology | (Quantity to be processed) | Steps taken |
|---|---|---|
| Dry Process : | | |
| Wet Process : | | |
| Others, if any, Please specify : | | |

**6. What provisions are available to check unauthorized operations of:**

Encroachment on river bank or wet bodies :
Unauthorized filling of low line areas :
Mixing with solid waste :
Encroachment in Parks, Footpaths etc. :

**7. How many slums are provided with construction and demolition waste receptacles facilities:**

**8. Are municipal magistrates appointed for taking penal action for non-compliance with these rules:** Yes No
[ If yes, how many cases registered & settled during last three years (give year wise details)]

**Dated:** **Signature of Municipal Commissioner**

**Form –IV**

**See [Rule (8)(3)]**

**Format of Annual Report to be submitted by the State Pollution Control Board / Committees to the Central Pollution Control Board**

To,

The Chairman,
Central Pollution Control Board,
PariveshBhawan, East Arjun Nagar,
Delhi-110032

1. Name of the State/Union territory :

2. Name & address of the State Pollution Control Board/Pollution Control Committee :

3. Number of municipal authorities responsible for management of municipal solid wastes in the State/Union territory under these rules :

4. A Summary Statement on progress made by municipal authorities in respect of implementation of **Schedule III**] : Please attach as Annexure-I

5. A Summary Statement on progress made by municipal authorities in respect of implementation of **Schedule IV** : Please attach as Annexure-II

**Date:**

**Place:**

**Chairman or the Member Secretary**
**State Pollution Control Board/**
**Pollution Control Committee**

**Form –V**
**See [ Rule14]**
**Accident reporting**

1. Date and time of accident :
2. Sequence of events leading to accident :
3. The type of construction and demolition waste involved in accident :
4. Assessment of the effects of the accidents
    a. on traffic, drainage system and the environment :
5. Emergency measures taken :
6. Steps taken to alleviate the effects
    a. of accidents :
7. Steps taken to prevent the recurrence
    a. of such an accident :
8. Regular monthly health checkup of workers at

a. Processing / recycling site shall be made

9. Any accident during the collection,
   a. transportation and treatment including
   b. processing and recycling should be informed
   c. to the Competent Authority (Local Authority) or
   d. Prescribed Authority

Date : Authorized Signatory
Place: Designation

[18-6/2014-HSMD]
Bishwanath Sinha, Joint Secretary