International Journal of Engineering and Management Research
www.ijemr.net
e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-2 (April 2021)
https://doi.org/10.31033/ijemr.11.2.15

Optimization of Material Recovery Strategies in the Demolition Phase of Buildings – A Case Study

Rajan D[1], Dr. M. Kranti Kumar[2] and Dr. S. Ramesh[3]
[1]Student, Department of Architecture, School of Planning and Architecture, Vijayawada, INDIA
[2]Assistant Professor, Department of Architecture, School of Planning and Architecture, Vijayawada, INDIA
[3]Professor, Department of Architecture, School of Planning and Architecture, Vijayawada, INDIA

[2]Corresponding Author: kranti.myneni@spav.ac.in

ABSTRACT

Globally, the construction industry is one of the most environmentally catastrophic industries, with a significant effect on the raw materials usage, their commitment of use throughout their whole life cycle, and the atmosphere in which they work. Between 1950 and 2010, global average material consumption rose from 5.0 t to 10.3 ton per capita per year, owing to population growth, industrialization, and increased socio-economic strength. Moreover, this industry uses 35% of produced energy and releases 40% of carbon dioxide into the Earth's atmosphere. One hundred fifty million tons of CDW is made in India according to the BMPTC, and less than 1% is reutilized properly added to that the 55% of total solid waste in India are from the construction industry. The waste produced during the demolition can be well utilized if managed and appropriately recovered, which directly reduces the virgin raw material usage in the new construction, decreasing the amount ending in the landfill. This study aims to understand the strategies and technology for material recovery after the building's life. The literature review will be taken up to list the different strategy in practice for material recovery. The techniques for material recovery are discussed to understand more in detail. This research helps find the other methods for material recovery and equipment and technology during the demolition and reconstruction of the RCC framed structure. The bottlenecks in the adoption of the various strategy are studied in this research.

Keywords— Construction Industry, Demolition Waste Management, Material Recovery

I. INTRODUCTION

The building industry contributes significantly to the global economy, accounting for about 12 percent of global GDP and involving various intermediate goods such as raw materials, additives, electrical appliances, and associated services. Owing to the continuing trend of people living in cities, increasing migration currents, and rising public-private collaborations in infrastructure growth, this trend is expected to expand in the immediate future. Around the same time, the construction industry is a significant waste source: houses use about 35 percent of the world's capital and 40 percent of total electricity, use 12 percent of the world's drinkable water, and emit almost 40 percent of global carbon dioxide emissions.[1] For many developed nations, solid waste disposal is a significant concern. Solid waste production grows in parallel with urbanization and industrialization, wreaking havoc on the environment. As a developing world, India faces substantial difficulties in handling various solid wastes. Currently, a significant amount of money is spent on dealing with multiple forms of solid waste. Construction and demolition (C&D) waste are some of these forms of debris. The building industry has undergone unprecedented growth over the last two decades.[1] Construction and demolition waste makes up a significant portion of destruction in developing countries, i.e., accounting for 55 percent of complete solid waste generated in India[2]. According to the BMPTC report, India produces one fifty-million-ton waste as construction and demolition waste in India, and less than one percent is recycled for energy recovery and material recovery.[3] Typically, such waste is disposed of in landfills, resulting in a significant depletion of energy and resource.

Furthermore, traditional disposal practices eventually lead to landfill capacity overload, which adds to the environmental burden and raises concerns about additional ecological and health risks. Even though this practice is more convenient, it has been the most remarkable environmental hazard in recent years. Since C&D wastes have few harmful and dangerous ingredients, they can react with other debris, causing greenhouse gas emissions. A few researchers have documented the reuse of C&D wastes in different building activities. Since it requires eco-friendly and renewable options, reutilization and recycling could be the best choice for managing C&D wastes. The 3Rs definition will help deter environmental destruction and natural resource loss by managing these wastes. C&D wastes have a wide range of characteristics depending on their source and composition. Various capable systems for the isolation and reuse of these wastes are now available on the market. These technologies are commonly known and relatively inexpensive. Despite its capacity, the amount of C&D waste that is reutilized,

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-2 (April 2021)
https://doi.org/10.31033/ijemr.11.2.15

processed, or reused is only around 10-40% in different countries due to a lack of knowledge about the demolition and recycling process and the economic advantages it provides in implementing such strategies that have less environmental impacts and increase the benefits/value of salvage materials.[4]

II. AIM

The paper aims to understand the strategies and technology for material recovery after the building's life

III. METHODOLOGY

This study is a pilot study for my thesis. The data regarding the demolition techniques, equipment, and material recovery strategies are collected through literature sources. This paper is all about integrating data to find the strategy and technology involved in the demolition phase of the building. This study's most important move is the literature review. A literature review necessitates extensive data collection on the topic. The online database and technical report assist in gathering the necessary information. Approximately 13 research papers collected information on demolition waste management, including technology, types of equipment on the market, and resource recovery strategies. Conclusions are drawn from the literature data analysis to summarize the reviewed data.

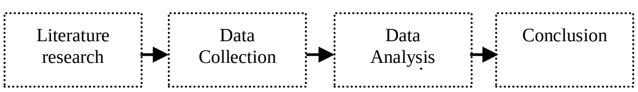

Figure 1: Methodology flow

IV. LITERATURE REVIEW

Buildings – Demolition

When houses and factory sites from the industrial revolution hit the end of their useful lives in the second half of the twentieth century, the construction industry started to consider demolition. Medium- and small-sized demolition firms could purchase the required equipment, such as excavators and trailer trucks, at that time. The primary responsibility was to demolish a house. Demolition debris was dumped on dumpsites until the 1970s. As a result, the waste could not be reused or recycled. Contaminations were not treated as toxic materials in the same way. Demolition was more of a logistical issue than a question of expertise. Currently, the demolition is more of a state of art task. Deconstruction is classified into four jobs: decontamination, foundation replacement, or Deconstruction of non-load bearing structures; demolition through machines; disposal, and recycle.[5] The possibilities of End life of the buildings are classified as Refurbishment, Demolition, Deconstruction. [1]

A. Refurbishment - "Process of restoring a structure to a former better condition or to revive it, including alterations such as remodeling and retrofitting, which can result in a completely different building."[1]

B. Demolition - "Process of arbitrary disassembling or destroying a building to clear the construction site, using heavy construction machinery quickly."[1]

C. Deconstruction - "Process of the selective dismantling of building components, part by part and avoiding damage, specifically for reuse, repurposing, and recycling."[1]

Demolition techniques vary based on the place to be destroyed, the amount of time required, the construction material to be demolished, the demolition's purpose, and how the rubble would be disposed of. The demolition sequence would be determined by factors such as the building, the venue, and the chosen demolition methods. Buildings destroyed in the order in which they were built, a process is known as "sequential demolition." Some forms of demolition are [5]

- Demolition of the building by Top-Down-Manual Method
- Demolition of the building by Top-Down- By Machines
- Demolition of the building by Wrecking Ball
- Demolition of the building by implosion (Usually bottom-up)

Other methods involved are Thermal processes, Abrasive processes, Electrical processes, Chemical processes.

In this paper, the debate focuses primarily on Deconstruction as an alternative to demolition, as this is the study's main subject. The deconstruction benefits in economic and environmental terms are proved in following this research paper. Figure 1 depicts the difference between linear construction and circular construction in terms of sustainability it yields.

Reduce	1 Changing our behaviour
Reuse	2 Reusing material
Recycle	3 Recycling and reprocessing material
Recover	4 Recovering energy
Landfill	5 Targeting Zero Landfill

Figure 2: Waste Scaling

Waste Scaling

Figure 2 depicts that the method to reduce debris amount is to improve people's attitudes, improving the way we produce and create goods. When it comes to waste reduction, purchasing is still a crucial step to take. Setting the correct requirements during procurement will have a

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-2 (April 2021)
https://doi.org/10.31033/ijemr.11.2.15

significant impact on the amount of waste generated. The term "reuse" refers to the use of secondhand manufactured materials. Material recycling involves turning debris into new products, while waste recovery is triggered using the trash to produce electricity. The last process involves the landfilling of entirely non-recyclable waste.[6]

Difference between the Traditional Demolition Methods & Deconstruction

Either selective or conventional demolition plans usually demolish buildings. [7]

Alternative 1 Deconstruction - The following deconstruction methods, as illustrated by Chini and Bruenig (2003) in practice for selective demolition, will be used. Remove the braces from the doors and windows. Kitchen fittings, pipe components, curtains, and doors can all be removed. Remove the plaster from the floor and walls, as well as the wires and tubing. Remove the roof, knock down the walls and floors. Floor by floor, repeat the process. Building materials reused in selective demolition are found and sold to retailers after being properly removed without fracturing. This structure is dismantled and processed in the same manner as the traditional solution after selective recycling materials. They illustrate the development of primary materials through

Demolition option	Implementation	Materials generated
Alternative 1: Selective Demolition	• Less energy resources – *More specialized equipment needed* • More labour – *Increased costs* • Onsite sorting • May require more transportation trips • More time needed • Needs more space for different bins • Need more project planning, training and information • Need specific competence	• Re-usable & Recyclable materials
Alternative 2: Conventional Demolition	• Extensive Energy resources – *Cranes, Explosives, Loaders etc.* • Less Labour • Less demolition time required • Limited onsite sorting • Less transportation trips • More landfilling	• Recyclable materials • Combustible materials • Waste

Figure 3: Conventional demolition vs. Deconstruction

Manufacturing processes from right to left (Initial start to use). However, on the selective demolition side, they depict a scenario for material recovery. In fig. 4, From the Selective demolition side to Raw material side, the processes that will be defined in the model will involve the processing of ready-to-use materials. During such a process as reusing/recycling, the materials are handled cautiously during the whole demolition process. The demolition energy used to demolish the structure is in materials/fuel or electricity/heat used to remove and prepare new or reuse same goods. The material moving possibilities for reusing/recycling are taken into account.

Alternative 2 Traditional demolition - Strong machines, hand axes, explosions, and other traditional methods to pull down the house. Materials are separated into various fractions such as concrete & brick rubbles, timber, Metals, and inert material at the demolition site, often without prior disassembly, recycling, energy recovery, and landfilling.

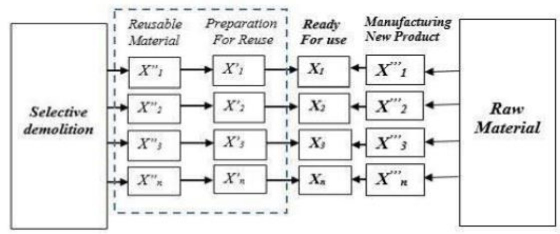

Figure 4: Deconstruction

The items collected are categorized, and the material that is recyclable material is shipped to a recycling facility to be processed into new goods (Demolition to Material recovery). The product obtained after recycling will be checked for quality. If the projected quality is not accepted, it

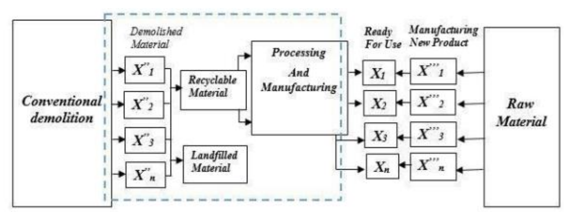

Figure 5: Traditional demolition

will be processed to manufacture the main product. For instance, Concrete cannot be recycled into fresh Concrete. The manufacture of new materials, such as aggregate, would be modeled from raw materials in this case.

Figure 6: Types of demolition equipment attachments

Types of Equipment – Demolition

Some of the equipment that is used in the demolition is a High reach arm, Hydraulic impact hammer, Hydraulic

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-2 (April 2021)
https://doi.org/10.31033/ijemr.11.2.15

Concrete crusher, Hydraulic splitter, Pusher arm, Calm shell. Some of the used attachments are Grapples, hammer, shear, Multiprocessor, Pulverizes, Buckets. The techniques used for the demolition are wrecking balls, shears, Push/Pull, Grabbing, Hydraulic breakers. [8]

Figure 7: Types of demolition equipment

Some of the advantages and disadvantages of the various techniques are listed below in table 1 [5]

Table 1: Pros and cons of various demolition techniques

Wrecking ball	Shears	Push/Pull	Grabbing	Hydraulic breaker
Very effective	Effective	Only applicable with masonry	Lightweight constructions	High reinforced concrete/thick constructions
Low control	Precise and controlled Deconstruction	Limited height	Limited height	No separation
No separation	Separation	Applicable for part of buildings(walls)	Separation	Precise
High noise emission	Limited noise emissions	Limited noise emissions	Limited noise emissions	High noise emission
Need clear surroundings	For controlled work	Expand height	Roof structures mainly of wood and light steel	Deconstruction of buildings

Material Recovery Strategies

The C&D waste in India comprises 40...50% debris (brick, mortar, plaster, dust); 20...30% waste wood (various scrap wood – stumps, boards, divisions, beams, paneling, shingles); 20 ... 30% mixed solid waste (panels painted or contaminated, metal, pitch-based products, glass, plaster, asbestos, and other insulation materials, petroleum products, sanitary, thermal and electrical items)[9]. More than 50% can be recycled or reused if proper technology and plan are adopted.[10]

Concrete

Concrete is usually made up of coarse aggregates, fine aggregates, cement, and water, which are then strengthened with manufacturing materials/by-products. When recycled, some of the possible outcomes are recycled concrete aggregates, manufacturing the precast materials like paver blocks, Kerbstone, drain cover, C&D blocks, which are proven to be stronger and economical than conventional ones, filler materials. Occasionally, during demolition, good-sized precast components are collected that can be reused or otherwise crushed and turned into recycled aggregates. The use of these recycled aggregates is limited. BIS and IRC codes, such as IS: 456, IS: 1343, or IRC: 112, regulate India's concrete development. All of these codes only permit the use of naturally occurring aggregates that meet IS: 383. A special requirement for using recycled aggregates in conjunction with naturally occurring aggregates must be created to solve these constraints. [11]Thus, the share amount of the recycled aggregate and the new aggregate ratio is made in the codebook IS 383. [12][4][13][1]

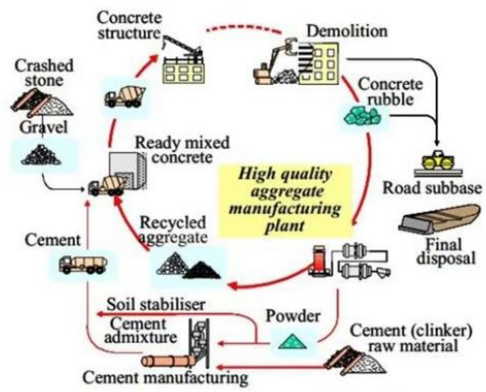

Figure 8: Concrete recycling process

Brick

Bricks are a common building material used in the construction of both residential and non-residential structures. On new residential building projects also makes up a large part of the overall C&D waste. Owing to inadequate internal handling and improper cutting, bricks are primarily treated as waste when broken or destroyed on the brick manufacturing line or the building site. The brick's high longevity makes it environmentally friendly in the sense that it can be reused repeatedly until the building is destroyed, and the non-reusable amount can be recycled for other beneficial purposes. When recycled, some of the possible outcomes are Low-cost bricks (Under plinth area) after removing the mortar, Brick aggregate (Fine or coarse), Brick pavers, or landscaping. As Concrete, the share proportion needs to be maintained as per the codebook when used as a brick aggregate. The bricks can

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-2 (April 2021)
https://doi.org/10.31033/ijemr.11.2.15

be used as a by-product in manufacturing the C&D blocks.[12][4]

Wood

Wood has a long operating life that is far longer than the life of the house. Consequently, unless consumed by termites or destroyed by fire, those items maintain their Engineering properties for a long time and can be reused, rendering them an environmentally sustainable commodity. Wood materials have two options: they can be reused or recycled to create a new product. Waste wood that cannot be reclaimed in its original state or is no longer available in the same shape and scale can be recycled into new particleboard, medium density fiberboards, animal bedding, or green energy. Such demolition materials such as asphalt, mortar, aggregates, sand, bricks, plastic, metals, and tiles must not be present in the recycled wood. For example, the door frame may be reused or recycled into wood chips for particleboard manufacturing.[12]

Tiles

The possibility of reusing is significantly less when compared to all materials. The tiles are very hard to remove without breakage and rendered useless to reuse when there is seepage behind the tiles. When recycled, some possible uses are Broken tiles to small pieces for landscape flooring, murals artifacts, tabletops, special effects in driveways, pedestrian subways. The tiles are crushed to aggregate and used as aggregate with the virgin material in a particular proportion.[12]

Metals, Plastics (PVC, etc.,)

Steel and aluminum are the two most common metals collected as waste during the demolition of a structure. Structural steel obtained can be reused if possible, without processing, or adjusted according to the requirements. The vital bonding procedure can be used to recycle aluminum waste. If caution is taken in the early stages, such as during planning, with a clear deconstruction strategy, the number of recycled scraps, such as household appliances, can be increased significantly without route the trash through a foundry. Aluminum can be recycled several times and is still in demand due to the need to protect the environment. As opposed to fresh aluminum's energy needs, recycling scrap aluminum consumes a fraction of the energy. Aluminum is infinitely recyclable and can be recast into its original shape, allowing it to be used in ways that are significantly different from its original function.[12]

Recycled scrap or waste plastic from demolition or building sites is reprocessed and converted into a range of usable items. Plastic polymers require more work to be recycled than other components such as glass and metals.[12]

Recycling Process – C&D

The following flow diagram depicts the process in which the C&D waste is recycled[2]

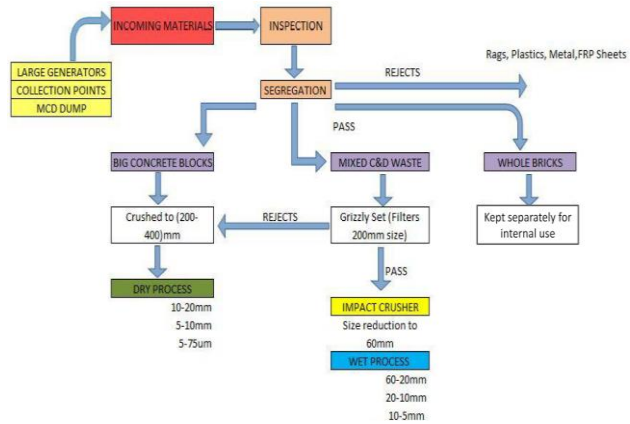

Figure 9: Recycling process

V. CONCLUSION

The traditional demolition and Deconstruction of the building is analyzed using the different data from the various research paper collected. Following are the results of comparing the conventional and Deconstruction adoption in the demolition of RCC building (1) Traditional demolition is still more cost-effective than Deconstruction. (2) For Deconstruction, the cost structure is more evenly divided between labor, supplies, transportation, and final disposal costs, while conventional demolition is more focused on disposal costs. (3) Deconstruction takes longer and requires more effort than conventional demolition. (4) For Deconstruction to be comparable with conventional demolition, landfill prices should be increased. In the material recovery strategies, the various material obtained in demolishing the RCC framed structure is listed and discussed. Following are conclusions made concerning the material recovery strategies. Concrete, brick, and metal have more recycling possibilities and bring more savings than any other material recovering. The material mentioned above has other advantages: when the RCC framed structure is demolished, Concrete, brick occupies more than 50% of the material waste produced, which can be processed for the future without much work like metal recycling. Aluminum has more recycling properties, unlike any other material. If so, demolishing a building is made of wood or has more wood material content to it. In that case, wood also can be reused. If so, it is adequately maintained. The average lifetime of wood without recycling is up to 100 years. Demolish requires multiple types of equipment, and some of the adequate equipment found are shear and hydraulic breakers. Other than demolition equipment, the transportation and recycling plant also need to be considered as it has a significant impact when analyzing the cost factors. Some of the material out of the Concrete are Recycled aggregate, Plastering after recycling block,

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-2 (April 2021)
https://doi.org/10.31033/ijemr.11.2.15

Pavement blocks. Some of the material out of the brick are recycled aggregate, low cos brick. In most cases, metals can be reused or recycled into different or same material. Aluminum, one of the metals, has more recycling ability, and the reusing depends on its usage in a lifetime. The tiles will not be used as tiles, but they can be used as recycled aggregate or flooring artwork.

REFERENCES

[1] G. Bertino, J. Kisser, J. Zeilinger, G. Langergraber, T. Fischer, & D. Österreicher. (2021). Fundamentals of building deconstruction a circular economy strategy for the reuse of construction materials. *Appl. Sci., 11*(3), 1–31. DOI: 10.3390/app11030939.

[2] *Exhibition and Conference Importance of C & D Waste Recycling for Municipalities*. (2018).

[3] Building Materials and Technology Promotion Council. (2018). *Utilisation of Recycled Produce Of Construction & Demolition Waste A Ready Reckoner*.

[4] M. S. Jain. (2020). Possible ways of re-utilization of the construction and demolition wastes in various construction sectors. *Sustainable Development and Environment*, pp. 88-109.

[5] P. Kamrath. (2013). *Demolition techniques and production of construction and demolition waste (CDW) for recycling*. Woodhead Publishing Limited.

[6] M. Sheidaei & E. Serwanja. (2016). Evaluation of recycling & reuse of building materials from demolition: Cost feasibility and environmental impact assessment. *Masters Sci. Thesis Master's Degree Program. Infrastruct. Environ. Eng.*.

[7] M. Theses & R. Citation. (2002). *ScholarWorks at WMU building deconstruction guidelines : Tools for recovering building materials*.

[8] S. O. Rathi & P. V Khandve. (2014). Demolition of buildings an overview. *Int. J. Adv. Eng. Res. Dev., 1*(06), 1–8. DOI: 10.21090/ijaerd.010643.

[9] I. E. Seftiuc & Ș. Vasiliu. (2011). Recycling Resulting From Demolition Case Study. *Reciclarea Prod. Rezult. Din Demolări., 61*(1), 65–72. Available at: http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=79907107&lang=pt-br&site=ehost-live.

[10] M. D. Saghafi & Z. A. H. Teshnizi. (2011). Building deconstruction and material recovery in Iran: An analysis of major determinants. *Procedia Eng., 21*, 853–863. DOI: 10.1016/j.proeng.2011.11.2087.

[11] I. Standard. (1996). Demolition of buildings - Codeofsafety. *Marg*,.

[12] CPWD. (2014). CPWD guidelines for sustainable habitat. Available at: www.cpwd.gov.in.

[13] S. Tates. (2003). Deconstruction and materials reuse in the United States. Available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.115.6066&rep=rep1&type=pdf.