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Carbon Emission Reduction of Redevelopment Projects through Construction and Demolition Waste

Somnath Maurya*
Final Year Post Graduate Student, Department of Building Engineering and Management, School of Planning and Architecture, New Delhi, India.
***Corresponding Author**
E-mail Id:- *som16nitrr@gmail.com*

Abstract- *In the present scenario construction and demolition waste is still seen as waste for landfills and it is not seen as a source of building materials. A huge amount of waste is generated by the construction sector and is left unprocessed. Because of increasing concerns about sustainability, natural resource depletion, and carbon emissions Construction and Demolition Waste can be key factors in overcoming these issues. The research aims to develop strategies that can be applied to a redevelopment project to bring down the carbon emissions associated with it.*

Keywords: *Building material, sustainability, carbon emission.*

Introduction

Because of increasing land costs and scarcity of land Redevelopment of properties has been identified as one of the key strategies to overcome housing shortage as well as to monetize vacant land lying with government agencies. A study by the World Economic Forum (WEF) suggests that 75% of construction waste, worldwide, is discarded. The United Nations Environment Programme (UNEP) reported that buildings and construction activities are responsible for more than 36% of the global energy consumed, and as much as 40%-50% of energy-related CO2 emissions (Taffese & Abegaz, 2019). Demand for a low carbon footprint can be a key factor in fostering innovation while motivating policymakers to encourage sustainable Construction (Badawy, 2020). Also, during the Covid-19 Pandemic, a lot of buildings were demolished and constructed to meet the required health facilities around the world. (Dasgupta et al., 2021)

The amount of C & D waste in India has been estimated to be 10 - 12 million tonnes annually and the proportion of concrete is estimated as 23 to 35% of total waste. Considering 30% percent of C & D wastes of 12 million tonnes as concrete, and 50% of the concrete as coarse aggregate.

Research suggests that although construction waste is a major contributor to solid waste it is still not widely seen as a source of building material (Shooshtarian et al., 2020). The highest contribution to waste generation is due to the demolition of buildings. Demolition of Pucca and Semi-Pucca buildings, on average generates 500 & 300 kg/ sq.m. of waste respectively. With the increasing demand for built spaces and scarcity of land, a trend of redevelopment projects is upcoming. (Anagal, 2014)

To begin with, a redevelopment project demolishing the existing buildings would be the very first step and the waste generated would be massive. And the generated waste needs to be transported before starting with the new construction. Various studies show C & D waste can be reused and recycled. And their performance can be assessed. (Solanki et al., 2022) So, in the case of a redevelopment project instead of discarding the waste generated if it can be used in any form, it would help in decreasing the waste and carbon emission associated.

Methodology

The research was done to understand and develop strategies for Construction and demolition waste to reduce the carbon emissions of redevelopment projects. Various literature studies, Indian standard codes, government guidelines, and case studies have been done to identify the potential building components which can be reused or recycled in a redevelopment project. A summary of reusable, recyclable, and replaceable materials up to what extent is identified and listed down. Further, the carbon emissions of virgin and alternative building materials were calculated to assess the carbon emission reduction potential of C & D waste.

Construction and Demolition Waste

Construction waste is generated whenever any construction/demolition activity takes place, such as building roads, bridges, flyovers, subways, remodeling, etc. It consists mostly of inert and non-biodegradable materials such as concrete, plaster, metal, wood, plastics, etc. As per CPCB, the components are dependent on the type of building but in general, it may comprise of the following materials (Adams et al., 2006): To assess, the quantum of waste modern approaches like laser scanning can also be helpful.

***Table 1**: Major and Minor components of C & D Waste*

Major Components	Minor Components
•Cement Concrete •Bricks •Cement plaster •Steel (from RCC, door/window frames, roofing support, railings of the staircase, etc.) •Rubble •Stone (marble, granite, sandstone) •Timber/wood (especially demolition of old buildings)	•Conduits (iron, plastic) •Pipes (GI, iron, plastic) •Electrical fixtures (copper/aluminum wiring, wooden baton, Bakelite/plastic switches, wire insulation) •Panels (wooden, laminated) •Others (glazed tiles, glass panes)

Buildings' lifespan can be calculated through various methods and depending on the age a waste management plant can be formulated for effective waste management on demotion. (Solanki & Paul, 2022). Large C&D projects in India regularly amass rubbish on the roadside, causing traffic congestion. Separate household garbage is thrown into nearby municipal bins or containers, as well as waste storage yards, resulting in bulky municipal waste and limiting its value for activities such as energy recovery and composting. (CPCB, 2017). For more than a decade, there has been a growing debate about how to deal with old public buildings, as the majority of the prominent structures are in visible disrepair. (Solanki & Paul, 2022).

Since major construction activities are dependent on raw materials like sand (for concrete and mortar), soil (for clay bricks), stone (for aggregates), and limestone (for cement), all of them have significant environmental implications during their extraction and manufacturing. Some of these minerals, particularly sand, are already in short supply (due to environmental bans and limitations), putting the construction sector at risk. (CPCB, 2017).

Carbon emissions of building materials

The life cycle of any material that is used in construction generally consists of different stages like excavation, processing, construction, operation, conservation, obliteration, waste, or recycling/ exercise. Each of these stages involves some kind of energy consumption and applicable CO2 emigration to be fulfilled. The embodied energy of a structure comprises two factors, videlicet the direct EE and the circular EE. Direct EE is the energy consumed for the transportation and installation of structure accouterments and products to the construction point. Indirect is the EE consumed to acquire, process, and manufacture the structure accouterments, including any transportation related to this conditioning. Indirect EE can be further divided into original and recreating EE.

Original EE is the energy consumed for the accession, transportation, and processing of raw accouterments to produce a product. The recreating EE is related to the energy consumed in the conservation, form, and relief of a product during its service life.

Recycling

Recycling is the process of gathering and processing items that would otherwise be discarded as waste and transforming them into new products. The time spent waiting for new materials to be manufactured and supplied is eliminated when recycled materials are used, lowering the cost of material manufacturing. (Alwadhenani, 2020). Recycling also increases project efficiency by providing a clean working environment for workers and repurposing C&D waste. Costs such as transportation would be avoided if recycling and reusing techniques were implemented on the construction site, which would be advantageous to both the contractor and the environment. (Alwadhenani, 2020). There have been a lot of studies that suggest that improper management of C & D waste has led to accidents on construction sites also. (Solanki et al., 2022)

Disposal, on the other hand, harms the environment and workers due to the pollutants produced. Trash and disposal procedures can also be costly and hazardous to workers. Recycling is always more efficient than disposing of C&D waste. (Alwadhenani, 2020). Carbon dioxide emissions are widely recognized as the primary cause of global warming. Recycling waste materials properly can reduce the demand for limited natural resources while also saving the energy required to process raw materials. Emissions from raw material extraction and transportation harm the environment. (Alwadhenani, 2020)

A large quantum of energy is saved during the recycling process because the birth process has a low energy demand. A typical illustration is the there-utilization of Steel attained from C&D waste that requires much lower energy as compared to the original process. Recycling concrete can save one billion gallons of gasoline, original to removing about 1 million buses from roads.

Case Studies

Two case studies were identified and selected, the first one is the Construction and demolition waste treatment plant to understand what kind of building materials are generated from these waste treatment plants and their uses and also, what are the source materials for these recycled products. The Second Case study is of a redevelopment project to understand the onsite practice of demolition, waste management, and utilization of C & D waste materials for new buildings.

East Delhi Municipal Corporation Construction and Demolition Waste Plant

The recycling Plant is Located at Shahdara Delhi and Plant was started in March 2013, this plant is under PPP mode with East Delhi Municipal Corporation. The waste processing capacity of the plant is 500 Ton per day (TPD). The plant can recover about 95% of incoming C&D waste and uses recycled sewage water for processing waste. The processing technology includes both dry and wet processing and around 95% of the incoming C&D waste is recycled and processed into aggregates and M-sand. Utilizing recycled materials, the unit produces finished products such as kerbstones, paver blocks, concrete bricks, and pre-cast reinforced cement concrete structures like drain slabs, roofing structures, etc. The balance 5% is a clay-like filter press material that can also be converted to useful products like bricks.

From the case study, a list of recycled products being generated at the EDMC plant is listed below which can be used as a potential resource for reducing the carbon emission of newer buildings.

Table 2: *Products Out of C & D Waste Generated at Site*

S.no	Recycled material
1	Concrete Tiles- Brick pattern, Chequered, Dumble Shape, Techtile pattern
2	Cement Concrete Blocks
3	Recycled Concrete aggregates- 10mm, 20mm, 40mm
4	Screened Soil
5	Stone Dust
6	Kerb Stones
7	Paver blocks

Redevelopment of General Pool Residential Colony at Sriniwaspuri New Delhi

The project is a redevelopment project undertaken by CPWD this involves the demolition of existing structures and the Construction of new buildings. For the demolition of existing structures, they have used Mechanical as well as manual methods on site.

The waste generated is manually segregated on site, and different elements like reinforcement, masonry, and bricks are segregated and collected on-site. All the reusable and salvage components of buildings like doors, windows, electrical appliances, etc. were removed first and then the demolition process started. The waste generated on-site like, the reusable elements sold to the local vendors and the recyclable components like debris is handed over to East Delhi Municipal Corporation and is tabulated below.

The case study found that Concrete (33.9%) and masonry (54.28%) contribute to the majority of demolition waste. It has been estimated that 89262 Sq.m of demolition would be done and a huge amount of waste will be generated at the site. As per the previous case study, it is possible to recycle 95% of the waste into building materials. Therefore, the redevelopment project holds the maximum potential for reuse and recycling.

Identification of reusable, recyclable elements and permissible replacement limits

Form various guidelines, IS codes, and literature a summarized table of recyclable, reusable elements along with their permissible limits are mentioned below-

Table 3: *C & D waste utilization guidelines*

1. Evaluation of Reusable/ Recyclables Items				
	Reuse, Salvage Items	**Recycle Items**		
1. Reuse and Recycle	Appliances	Acoustical ceiling tiles	As per availability	C & D Waste Management Rules, 2016.
	Bathroom Fixtures	Asphalt	As per availability	
	Bricks	Asphalt Shingles	As per availability	
	Masonry Stone	Carpets	As per availability	
	Structural Steel	Concrete	As per availability	
	Cabinets	Drywall	As per availability	
	Timber boards	Fluorescent Lights	As per availability	
	Door and windows frames	Plastic Film (sheeting, packaging)	As per availability	
	Door and windows Shutters	Cellulose Insulation	As per availability	
	Flooring Tiles	Ceiling tile	As per availability	
	Stone tiles/ Platforms	Concrete masonry tile	As per availability	
	Lighting fixtures	Ductwork	As per availability	
	Metal Framings	Fences/posts	As per availability	
	Partitions and Ceiling Panels	Fiberboard	As per availability	
	Pipes	Fiber Glass	As per availability	
	Accessories hardware for furniture	Insulation	As per availability	
	PVC water tanks	Wallboard	As per availability	
	Roofing Sheets	Pilings	As per availability	
	Fabrics of tensile structure	Drainage or backfill aggregates	As per availability	
2. Recycled Material Replacement guidelines (Recycled Materials from C & D Waste)				
Components	**Material Replacement/ Substitute**		**Percentage Replacement (%)**	**Reference Document**
For Plain Cement Concrete	Recycled Concrete Aggregate		25	NBC 2016 Vol 2
For Reinforced Cement Concrete (M25)	Recycled Concrete Aggregate		20	
For Reinforced Cement Concrete (>M15)	Recycled Concrete Aggregate		100	
Brickwork	CCB		100	Construction and Demolition Waste Management Rules, 2016.
	Reuse of Brick		Depends on the Availability	
Kerb Stone	Recycled blocks		100	
Pavements	Recycled blocks		100	
Soil	Reclaimed Soil		100	
Base Refill	Broken Brick Bats, Debris		30-50	IRC 2017
Manhole covers, precast service ducts	Recycled blocks		100	C & D Waste Management Rules, 2016.
Graded Aggregate of size 10mm – 5 mm and up to 150 mm for Sub base of internal roads & paths.	Recycled Concrete Aggregates		Up to 100	IRC 2017

Carbon Emission Reduction Potential Matrix

From various research papers and guidelines, the carbon emission factor associated with conventional and recycled products is mentioned below. It can help assess how much carbon emission reduction is possible by adopting these alternative building materials.

Table 4: *Carbon Emission Reduction Potential Matrix*

Potential Carbon Emission Reduction Strategies		Conventional Material	When Recycled/ Reused	Possible % CO2 emission reduction
Material / Element	**Sub Component**	**CO2 emission kg/kg**	**CO2 emission kg/kg**	
Concrete	0% Replacement of RCA	0.1	-	
	25% Replacement of RCA	-	0.00088	0.22
	50% Replacement of RCA	-	0.0995	0.48
	75% Replacement of RCA	-	0.09929	0.71
	100% Replacement of RCA	-	0.09906	0.94
Masonry	Conventional Brick	0.22	When 100% Replacement by fly ash bricks	96.36
	Fly Ash Brick	0.008		
Structural Steel	Reinforcement Bars	2.71	0.44	83.76
Door, windows frames, and Shutters	Extruded Aluminum products	11.2	1.98	82.32
	Timber	1.56	1.248	20
Pavement	Recycled Pavement Blocks	0.16	0.1296	19
Bathroom Fixtures		0.66	0.04	94.5
Cabinets	Plywood	1.07	0.08	92.79
	MDF	0.72	0.05	93.09
	Glue Laminated Timber'	0.84	0.05	93.55
	Particle Board	0.84	0.06	92.48
Stones	Granite	0.64	0.02	97
	Limestone	0.087	0	96.55
	Marble	0.116	0	96.85
	Sandstone	0.192	0.01	96.74
	Slate	0.058	0	96.64
Metal Framings	Iron	1.91	0.08	95.72
Pipes	PVC	2.51	0.16	93.46
	Steel	1.37	0.08	94.46
PVC water tanks	-	2.61	0.07	97.25
Asphalt Shingles	-	0.3	0.01	96.02
Carpets (Per Sq.m)	-	3.9	0.36	90.89
Cellulose Insulation	-	1.47	0.09	93.79
Fiber Glass	-	1.54	0.06	95.89
Insulation	Wood wool board insulation	0.53	0.02	96.02

4.2 Challenges associated with recycled materials

In the recycling process of any material, there are various challenges associated with waste handling, quality management, physical, and chemical properties, and the cost associated with it. A few challenges associated with the material related to the Indian Context are enlisted below.

Table 5: *Challenges associated with recycled materials*

S.no	Challenges	Explanation
1	Poor Quality Raw Materials from C & D waste	From various types of research, it has been found that only a part of C & D waste recycle aggregate is suitable for nonstructural products. The type of aggregate and its source used in earlier concrete is also a major factor. (Rastogi et al., 2022) The aggregate could be contaminated with salts, bricks and tiles, sand and dust, timber, plastics, cardboard and paper, and metals. (Rao et al., 2007) To produce aggregates for structural use, there is a major challenge associated with the physical properties as well as chemical properties of recycled aggregates. The water absorption value is much higher than that of the natural aggregates whose absorption is about 0.5–1%. The high porosity of the recycled aggregates can mainly be attributed to the residue of mortar adhering to the original aggregate. This affects the workability and other properties of the new concrete mix. Physical properties such as bulk-specific gravity, water absorption, and abrasion vary and they interfere with the property of concrete. The end use of aggregates and other products recovered from these wastes depends on their quality in terms of cleanness and soundness which can only be achieved by high-end processing methods.
2	BIS Specifications	There are very few BIS codes that talk about Recycled construction waste products. Research done at the individual level is considered a benchmark. Recent revisions on BIS 383:2016 and IRC 121:2017 allowed the specific uses of recycled products within certain restrictions. Although these codes discuss the physical and chemical properties of concrete because of variation in the quality of RCA there must be specific guidelines related to mixing proportions, etc. to overcome the challenges of the use of RCA.
3	Quality and Performance	Quality and Tests of other recycled products are compared with the standards of their native products. There’s a need to develop specific standards for each material.
4	Certification	The lack of certification of these products results in a lack of confidence amongst buyers. Certifications such as CRRI certification of recycled aggregates for use as Granular Sub Base in road construction are useful. Inclusions of green certification for concrete pavers had been recently added to GRIHA certification. But there is a need for further addition of products.
5	Material Processing Energy	C&DW recycling requires more energy than the energy required to obtain natural sand and aggregate, implying material energy tradeoffs in C&DW recycling in India. (Jain et al., 2021)
6	Transportation Cost	Transporting waste over large distances makes the idea of using C&D waste uneconomical. Depending upon the complexity of projects they needs to be planned accordingly. (Moza et al., 2022). Installation of appropriately located recycling crusher units and mobile recycling plants can help in lowering barriers against recycling of construction & demolition waste.
7	Embodied Energy	There is a lack of data regarding the embodied energies associated with the reuse or recycling of c & waste in the Indian context.

5.0 Conclusion

In this research, an attempt has been made to discuss the utilization of waste products and the carbon emission reduction associated with them. These matrixes are developed in keeping in view the amount of data and information available. Various recent developments in this field have been analyzed and documented for the evolution of this matrix. These matrixes can be applied to any demolition, construction, or redevelopment project which comprises both demolition and construction of newer buildings. These matrixes can help in optimizing the waste management process and will promote the utilization of waste.

Although increasing demand for building materials, depletion, and scarcity of natural resources had made innovators to looks for alternate building materials. From the study, it can be concluded that utilization of C & D waste can be an effective solution for alternate building materials helping mitigate the problems of solid waste management.

The numerical data for carbon emissions shows a very promising outcome in terms of carbon emission reduction but due to the lack of reliable sources for carbon emissions databases for Indian contexts the carbon emission reduction values are not truly reliable. In the present scenario, there are various challenges associated with the recycling of C & D waste, its products, and its utilization. Thus, it cannot be clearly said that recommending the utilization of c & d waste materials only based on carbon emission factors would not be feasible.

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