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A Review of Recyclable Building Materials for Sustainability in India

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Abstract- Construction and demolition waste (C&DW) poses significant environmental challenges and resource scarcity concerns, particularly in rapidly growing economies like India. Despite generating an estimated 150 million tonnes of C&D waste annually, the country recycles just one percent of it, highlighting the urgent need for effective waste management strategies. This paper delves into the complexities of C&D waste management, exploring its sources, composition, and current practices in India. The study evaluates the magnitude of C&D waste generation, citing estimates ranging from 12 to 175 million tonnes per annum, underscoring the pressing demand-supply gap in construction materials. It examines the challenges of managing C&D waste, especially in smaller projects where waste segregation and reuse remain ambiguous. The paper proposes scalable solutions for effective waste management, drawing insights from successful international pilot projects.

Furthermore, the paper outlines the composition of C&D waste, categorises it into major and minor components, and discusses the potential reuse of materials like concrete, bricks, tiles, wood, and metals. It emphasises the importance of recycling C&D waste to alleviate resource scarcity and reduce environmental impact. The paper also highlights current recycling practices in India, showcasing operational waste recycling plants across various cities. It discusses using recycled materials in construction projects and addresses regulatory barriers hindering the widespread adoption of recycling practices. In conclusion, the study advocates for proactive measures to minimise C&D waste generation and enhance recycling efforts. It underscores the crucial role of architects and designers in promoting sustainable construction practices and recommends integrating waste management plans into project management frameworks. India can transition towards a more sustainable and circular construction economy by fostering stakeholder collaboration and leveraging existing technologies.

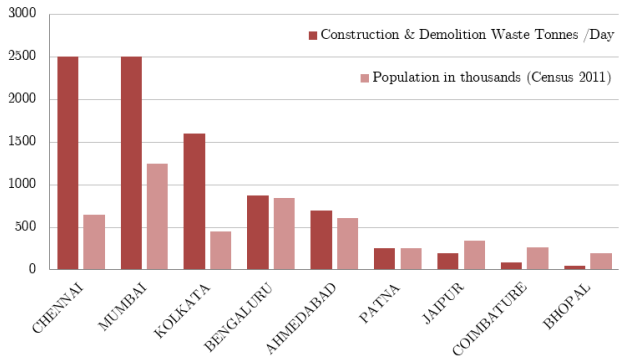
Keywords- Construction and Demolition Waste, Waste Management, Recycling, Sustainable Construction

INTRODUCTION

Construction and demolition waste (C&DW) encompasses waste generated from all activities involved in the construction, maintenance, demolition, and deconstruction of various structures, including buildings and civil works, as well as during natural disasters (US EPA, 2016). With the rapid expansion of the Indian construction sector, a significant demand-supply gap has arisen for construction materials such as sand, limestone, and aggregates. Moreover, the substantial volume of untreated construction and demolition (C&D) waste poses substantial challenges, particularly in areas characterised by

residential, institutional, industrial, or commercial construction activities (VG Ram, SN Kalidindi 2017). A recent Delhi-based non-profit organisation Centre for Science and Environment (CSE) report revealed that India only recycles one percent of its construction and demolition (C&D) waste. The report, released on August 25, 2020, indicates that the country generates an estimated 150 million tonnes of C&D waste annually, according to the Building Material Promotion Council. However, the official recycling capacity remains modest at 6,500 tonnes per day, accounting for merely one percent of the total waste generated.

Figure 1. C&D waste generation in 9 cities



Source: Prepared in compliance of Rule 10 sub-rule 1(a) of C & D Waste Management Rules, 2016

Due to the unavailability of data for these cities, 25% of MSW was taken as C & D waste based on the TIFAC 2001 study. Forecast estimates: Currently, C & D waste generation in India accounts for up to 23.75 million tons annually, likely to double by 2016. (International Society of Waste Management, India). Estimates of the quantity of construction and demolition (C&D) waste generated are available from various sources, providing valuable insights into the scale of this issue. These estimates encompass a wide range of figures, highlighting the challenges in accurately quantifying C&D waste. The Technology Information, Forecasting and Assessment Council (TIFAC) estimated 12 to 15 million tonnes (MT) in 2001.

Similarly, the Ministry of Environment and Forests (MoEF) projected a 10 to 12 MT range in 2010. The Central Pollution Control Board (CPCB) provided a narrower estimate of 12 MT within the same timeframe. The Building Material and Technology Promotion Council (BMTC) also reported a substantial increase, indicating a range of 165 to 175 MT annually between 2005 and 2013. These estimates underscore the complexity of managing C&D waste and the need for comprehensive strategies to address this growing environmental challenge. The primary challenge accompanying this surge in construction is the imbalance between material demand and supply. Exploring alternative sources presents a viable solution; repurposing C&D waste has immense potential to revolutionise the sector by significantly replacing traditionally mined materials.

Figure 2. Sorted Demolition Waste on Site

These wastes are heavy, have high density, are often bulky, and occupy considerable storage space on the road or in communal waste bins/containers. It is not uncommon to see huge piles of such waste. Several studies have been done on the use of concrete after demolition. There are two types of waste generators: the first is bulk generators (roads, bridges, flyovers, flats, malls, etc.), and the second is small generators (houses and small buildings). However, when we

focus on small projects such as buildings where C & D waste comes from a small scale, how to manage and reuse this waste has not yet been fully clarified. Therefore, it is important to address the recyclable materials from small buildings and reuse them in different methods. However, successful pilot projects in countries such as The Netherlands and Germany showcase that these barriers can be overcome even in big construction projects. Scaling up best practices to a critical number will foster technological progress and stakeholder cooperation. The market uptake will be fast once the right innovative products, processes, and business models are established. (Schuttelaar 2018). If measures to minimise and handle construction and demolition waste are not adopted in a developed and efficient manner, it can impact the environment (Y. K. Raj 2021).

UNDERSTANDING THE CONSTRUCTION AND DEMOLITION WASTE

Construction and demolition (C&D) waste is generated from the construction, renovation, repair, and demolition of houses, large structures, roads, bridges, piers, and dams. C&D waste includes bricks, tiles, stone, soil, rubble, plaster, drywall or gypsum board, wood, plumbing fixtures, non-hazardous insulating material, plastics, wallpaper, glass, metal (e.g., steel, aluminium), asphalt, etc. However, C&D waste does not include any hazardous waste as defined under the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016. Estimates vary, but a commonly accepted estimate is that between 15% and 20% of municipal solid waste comes from construction and demolition projects. The chart above categorises construction and demolition (C&D) waste based on its generation source. C&D waste is inherently complex due to the diverse building materials involved. Generally, C&D waste comprises both major and minor components. Major components include cement and concrete, bricks, cement plaster, steel (derived from reinforced concrete, door or window frames, roofing support, staircase railings, etc.), rubble, and various types of stone such as marble, granite, and sandstone. Timber or wood, particularly from demolishing older structures, represents another significant component. Minor components encompass conduits (made of iron or plastic), pipes (galvanised iron, iron, or plastic), electrical fixtures (comprising copper or aluminium wiring, wooden batons, Bakelite or plastic switches, wire insulation), panels (including wooden and laminated varieties), glazed tiles, glass panes, among others (J. Singh, 2020). India generates an estimated 25–30 million tonnes of C&D waste annually, with an additional 40–60 kilograms per cubic meter (kg/m3) produced during construction, minor repairs, or renovations (J. Singh, 2020). Mismanagement of construction and demolition waste presents a significant urban challenge, contributing to air pollution and environmental degradation. Extensive areas of lowland are engulfed by C&D waste, leading to substantial land devaluation, amounting to billions of dollars. Unregulated dumping in lakes and rivers further exacerbates environmental harm, posing risks to water bodies and ecosystems.

WHY INDIA NEEDS RECYCLING OF C & D WASTE

The imperative for recycling C&D waste in India becomes evident amidst the current material scarcity confronting the building and construction industry. With the country generating an estimated 150 million tonnes of C&D waste annually (CSE), its recycling capacity remains alarmingly low, hovering at around 6,500 tonnes per day, a mere 1.3% of the total waste generated. The lack of uniformity

among cities in quantifying and characterising C&D waste hampers effective segregation

strategies. Moreover, the absence of updated strategies to incorporate new-age construction materials exacerbates the challenge. Establishing a robust C&D waste collection system is imperative for cities to address this issue. While mature technologies for waste management exist in India and are already in use in cities like Delhi and Ahmedabad, numerous initiatives predate the notification of the C&D Waste Management Rules in 2016.

Figure 3. Categories of C&D wastes

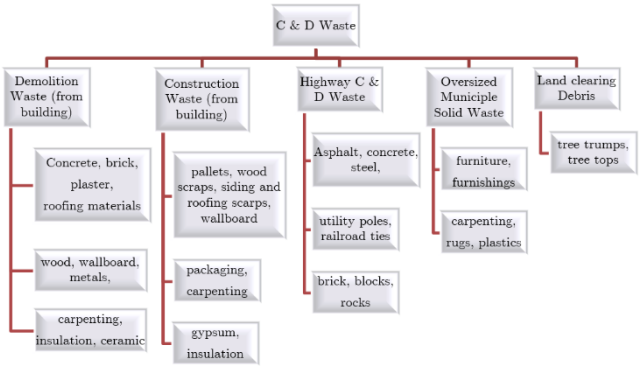


Table 1. C&D waste estimates for India

Year	Authority/Institute	Estimate (MT)
2000	Ministry of Urban Development	10 to 12
2001	Technology Information, Forecasting and Assessment Council, Department of Science and Technology	10 to 15
2010	Ministry of Environment and Forest	10 to 12
2013	Centre for Science and Environment	530
2014	Ministry of Urban Development	No Estimates
2015	Ministry of Urban Development	10 to 12
2015	Development Alternative and GIZ	750
2016	Ministry of Environment, Forest and Climate Change	530
2017	Building Material and Technology Promotion Council	150

The Youth for Unity and Voluntary Action (YUVA) championed a decentralised debris management solution in Navi Mumbai as early as 1999, with City and Industrial Development Corporation (CIDCO) support. This collaboration resulted in recycling over 1,500 tonnes of C&D waste between 2002 and 2006. However, despite its success, the CIDCO YUVA Building Centre (CYBC) was compelled to cease operations in 2012 due to a lack of policy and market support (Brick Off the Wall, CSE). The positive development is that the Bureau of Indian Standards has permitted the utilisation of concrete made from recycled materials and processed C&D waste. The Development and Demolition Waste Rules and Regulations of 2016 also mandate using recycled materials. Furthermore, the Swachh Bharat Mission has recognised the imperative of C&D waste management.

CURRENT PRACTICE ON REUSE OF C & D WASTE IN INDIA

Projections for the material requirements of the housing sector indicate a shortfall of approximately 55,000 million cubic meters, with an additional 750 million cubic meters of aggregates needed to meet the road sector's targets. Utilising aggregate material from construction and demolition waste could help alleviate the demand-supply gap in both sectors. Additionally, recoverable items such as bricks, wood, metal, and tiles are recycled, along with concrete and masonry waste, constituting over 50% of the total waste from construction and demolition activities. Cities including Delhi, Gurugram, Noida, Ghaziabad, Bengaluru, Chandigarh, Hyderabad, Indore, and Ahmedabad each boast at least one building waste processing plant, either managed by local authorities or operating under public-private partnerships, as indicated by a survey conducted by the Centre for Science and Environment (CSE). IL&FS IESL Delhi has notably operated a large-volume C&D Waste plant in Burari, successfully producing numerous value-added products from recycled sand and aggregate. A list of available waste recycling plants in India is provided in Table 2. Concrete and masonry waste is recycled in various countries abroad, including the UK, USA, France, Denmark, Germany, and Japan.

However, construction agencies like CPWD state that Indian laws allow using solely naturally sourced building materials. The IS: 323-1970 Indian standard specification concerning aggregates for concrete, established by the Bureau of Indian Standards (BIS), specifies that concrete can only be produced using naturally acquired materials. Construction agencies often reference this regulation to refrain from employing recycled C&D waste.

Table 2. C&D waste recycling plants in India

S. No.	City	Place	Capacity
1	Delhi	Burari	2000 TPD
		Mundka	150 TPD
		Shastri Park	500 TPD
		Rani Khera	1000 TPD
		Bakkarwala	500 TPD
		Maidan Garhi	1000 TPD
		Libaspur	500 TPD
2	Noida	Sector 80	150 TPD
3	Gurugram	Basai	300 TPD
4	Ghaziabad	Ghaziabad	150 TPD
5	Thane	Daighar	300 TPD
6	Indore	Devguradia	100 TPD
7	Hyderabad	Jeetimedla	300 TPD
8	Bengaluru	Chikkajala	1000 TPD
9		Kannur	750 TPD
10	Ahmedabad	Gyaspur Pirana	1000 TPD
11	Tirupati	Tukivakam Village	150 TPD
12	Vijayawada	Vijayawada	200 TPD
13	Chandigarh	Industrial Area Phase 1	150 TPD
14	Surat	Surat	300 TPD

Source: Book – Another brick off the wall (CSE)

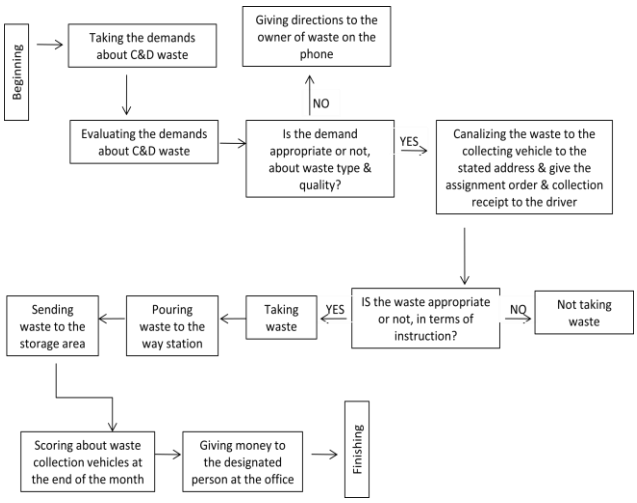
METHOD OF COLLECTING C&D WASTE

Before implementing the system, it is crucial to acknowledge the importance of waste segregation. The project supervisor should furnish clear instructions for segregating C&D waste at the construction site to facilitate its transportation for recycling. Concrete, wood materials, metals, clay, and bricks should be segregated separately. The process of collecting construction and demolition waste is elucidated in Figure 3.

PROCESS OF RECYCLING ACCORDING TO MATERIAL (major component from construction & demolition of buildings)

Concrete- Wastage of concrete can be transported to the washing and waste recycling plant for processing. The C&D waste processing systems help convert this waste into Recycled sand and aggregates that have various uses in various construction applications. Waste recycling involves a combination of crushing, washing, screening, and separating waste to ensure maximum waste treatment and minimum landfill. These processes should consider wet recycling to minimise pollution and dust particles left in the environment.

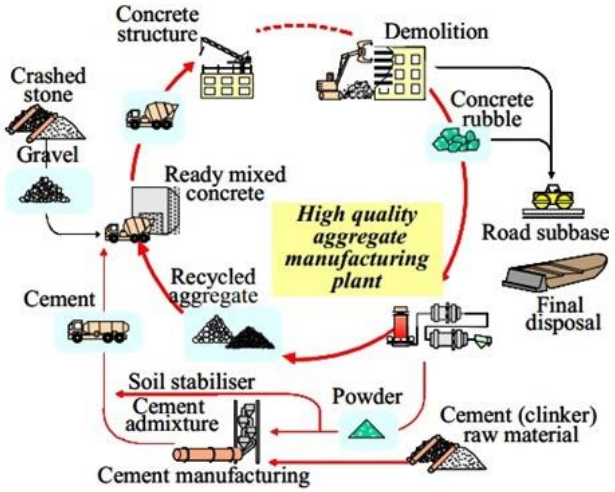
Figure 3. Method of Collecting And Recycling Waste



Bricks- Recycled bricks can be crushed and utilised for various unique applications. Companies often purchase them as substitutes for aggregates (such as gravel) in construction projects. Bricks can also be chipped and used in landscaping. The resulting chips are durable and

withstand harsh environmental conditions, including cold, windy, or wet climates. Additionally, if bricks are finely broken down, they can be used as a substitute for sand or incorporated into the production of new bricks. Sioux City Brick in Iowa produces an exceptional brick powder that finds applications in baseball diamonds or running tracks. Moreover, recycled bricks can be utilised to manufacture wall panels and plywood.

Figure 4. Process of recycling concrete waste



Source: Article on C&D waste (the constructor company)

Figure 5. Mosaic Garden Tiles

Source: Article on DIY projects from broken tiles (Architecture art & design)

Tiles- Ceramics are recycled by breaking into amorphous forms using large grinding machines, flat tamping tools, or a large hammer. Once they are transformed into powder (amorphous form), they can be distributed onto soil without adverse effects, effectively diverting them from landfills. Broken ceramic tiles can be repurposed to create mosaic garden tiles, while roof tiles can serve as interior decoration.

Wood materials- Wood waste holds significant potential for reuse and recycling across various industries. It can be repurposed as a valuable building material or recycled into mulch for landscaping, contributing to sustainable land management practices. Moreover, wood waste can be processed into pulp for paper production, reducing the demand for freshly harvested trees and conserving natural resources. Additionally, these waste materials often serve as fuel for brick-making and are utilised to some extent in cooking processes, especially in medium to large establishments. Segregation of wood waste based on size and quality is essential to optimise its reuse. Once segregated, the waste is shredded into fine sawdust, which can be utilised in several beneficial ways. It can act as a growing medium for edible mushrooms or nutrient-rich soil for plants, promoting agricultural sustainability.

Furthermore, it is a crucial raw material for manufacturing biomass fuel pellets, contributing to renewable energy production. Additionally, it finds application as the primary material for producing density boards or plywood, enhancing the sustainability of construction practices. Moreover, the fine sawdust can be used as bedding material for pets, ensuring their comfort while minimising waste. Lastly, it can be processed into charcoal, offering an eco-friendly alternative to traditional charcoal production methods. Overall, efficiently using wood waste presents numerous opportunities for resource conservation and sustainable practices across various sectors.

Stone- Stone waste can be transported to a recycling plant for processing, where various treatments are performed to convert it into crushed, broken pieces suitable for a wide range of construction applications. Recycling typically involves crushing, washing, screening, and separating the waste to ensure effective treatment. The reused and crushed stone products find diverse applications, such as paving or filling roads, crafting street furniture and gardening features, renovating blocks and slabs in marble and granite, and manufacturing resin tiles and crushed materials for terraces. These practical examples highlight the versatility and sustainability of utilising recycled stone waste in various construction projects.

Metals- Metal recycling follows a process similar to standard recycling procedures. Metals are sorted based on their properties, highlighting the importance of understanding metal characteristics for effective recycling and environmental sustainability. Recycling encompasses various stages: collection, sorting, processing, shredding, melting, purification, and solidifying the refined metal. Subsequently, the purified metal bars are transported to factories for further utilisation. This comprehensive approach to waste recycling ensures the efficient reuse of metals while minimising environmental impact.

Gypsum- The recycling process for gypsum mirrors conventional recycling procedures. Initially, gypsum materials such as drywall, plasterboard, and wallboard are collected and sorted based on their properties. A tolerance of up to 2% contamination is typically accepted during this sorting stage. Subsequently, the waste recycling process encompasses collection, sorting, processing, crushing, and converting gypsum into fine powder. The fine powder is then transported to factories where it is used to manufacture new plasterboards, typically by mixing it with other necessary materials. This holistic approach to gypsum recycling ensures efficient resource utilisation and contributes to sustainable manufacturing practices.

CONCLUSION

Architects or design team owners should prioritise understanding the significance of the waste stream. Their pivotal role in design decisions directly influences the choice of building materials. So, the higher they know the building materials and optimum sizing that may refer the lower the construction waste produced. Even the brief information they may give about waste generation and its effects on their clients may boost recycling and reuse options of generated waste in the construction site. (N. Cosgun, B. Salgin 2012). Also, the architect should suggest using recycled building materials such as precast recycled concrete blocks, garden pavers, and topsoil (obtained from excavation on the site) to their client. The designer can also suggest using on-site packaging and other metal scraps to design the interior spaces. The designer's role needs not be restricted to layout, and the design should move similarly to the creation phase. Still, by supplying good coordination and verbal exchange with the contractor and the builder, they may contribute to reducing or preventing construction wastes generated during the building construction phase. The construction or demolition waste management plan should be designed beforehand to take the necessary precautions to minimise the negative impact on the environment and human health. Handling the C&D waste from the construction or the demolition site can be added to the project management documents to minimise its negligence.

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