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Resource Efficiency in the Indian Construction Sector

Market Evaluation of the Use of Secondary Raw Materials from Construction and Demolition Waste

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List of Abbreviations

AEP	Ahmedabad Enviro Projects Ltd.
AMC	Ahmedabad Municipal Corporation
AUDA	Ahmedabad Urban Development Authority
BBMP	Bruhat Bengaluru Mahanagara Palike
BHK	Bedroom Hall Kitchen
BMC	Bhopal Municipal Corporation
BOT	Build-Operate-Transfer
BMRDA	Bengaluru Metropolitan Region Development Authority
CAPEX	Capital Expenditure
CBRI	Central Buildings Research Institute
CCMC	Coimbatore City Municipal Corporation
CCRS	Comprehensive Complaint Redressal System
C&D	Construction and Demolition
CIDCO	City and Industrial Development Corporation of Maharashtra Ltd.
CII-IGBC	Confederation of Indian Industry – Indian Green Building Council
CMC	Chennai Municipal Corporation
CMDA	Chennai Metropolitan Development Authority
CRRI	Central Roads Research Institute
CSE	Centre for Science and Environment
DoBC	Department of Building Construction
DPR	Detailed Project Report
EDMC	East Delhi Municipal Corporation
FAR	Floor Area Ratio
FSI	Floor Space Index
GBCA	Green Building Council of Australia
GDP	Gross Domestic Product
GSB	Granular Sub Base
IEC	Information Education Communication
IEISL	IL&FS Environmental Infrastructure and Services Ltd.
IHSDP	Integrated Housing and Slum Development Programme
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IT	Information Technology
IL&FS	Infrastructure Leasing & Financial Services Corp.
INR	Indian Rupees

JMC	Jaipur Municipal Corporation
JCB	Joseph Cyril Bamford
KMC	Kolkata Municipal Corporation
KMDA	Kolkata Metropolitan Development Authority
LEED	Leadership in Energy and Environmental Design
MCD	Municipal Corporation of Delhi
MCGM	Municipal Corporation of Greater Mumbai
MHADA	Maharashtra Housing and Area Development Authority
MIDC	Maharashtra Industrial Development Corporation
MLA	Members of Legislative Assembly
MMR	Mumbai Metropolitan Region
MMRDA	Mumbai Metropolitan Region Development Authority
M-Sand	Manufactured Sand
MSW	Municipal Solid Waste
MT	Metric Tonne
NDMC	North Delhi Municipal Corporation
NOC	No Objection Certificate
PMC	Patna Municipal Corporation
PPC	Portland Pozzolana Cement
PPP	Public Private Partnership
PSU	Public Sector Unit
PWD	Public Works Department
RCC	Reinforced Cement Concrete
RDF	Refuse Derived Fuel
RMC	Ready Mix Concrete
RWA	Resident Welfare Association
SDMC	South Delhi Municipal Corporation
TIFAC	Technology Information, Forecasting and Assessment Council
TNHB	Tamil Nadu Housing Board
ULB	Urban Local Body
USD	US Dollars
USGBC	United States Green Building Council

Chapter 1: Introduction

1.1. Objective and Scope of Report

The construction sector is an important driver of the Indian economy but it is also extremely resource intensive. The sector generates substantial amount of waste from the process of construction and demolition of buildings and infrastructure. Experience from other countries shows that properly processed Construction and Demolition (C&D) waste can be used as a raw material for construction. In India, C&D waste is poorly managed, usually resulting in illegal dumping that causes nuisance and environmental degradation. Therefore, management of C&D waste assumes prime importance; with the potential to reduce environmental pollution as well as contributing to the sustainable consumption of resources in the construction sector by decreasing reliance on mining of primary raw materials. The objective of this report is to assess the generation and current management status of C&D waste in India and draw conclusions on the potential of C&D waste as an alternative of primary raw materials used in the construction sector. The report attempts to present a snapshot of the status of C&D waste generation and management in 10 surveyed cities across India, establish scenario based projections of C&D waste in India, and present technical and economic feasibility of products made with C&D waste.

1.2. The Construction Sector in India Today

Construction in India is poised to become the world's third largest construction sector by 2018 (Global Construction Perspectives and Oxford Economics, 2015). It currently contributes about 7% to India's GDP (2014). Market forecasts for the 12th Five Year Plan period (2012-2017) indicate that the cumulative output of the construction industry is likely to be INR 52.31 billion (USD 790 million); contributed almost equally by the buildings and infrastructure segments[1] (Planning Commission, 2012). The Indian government has doubled the proposed public spending on the sector to USD 1 trillion (Figure 1A). However, resource constraints may limit public investment and the share of private investments is expected to increase significantly in the future (Equity Master, 2012).

[1] Buildings include residential, commercial, office, hospitality, industry and retail; while infrastructure includes structures such as roads and highways.

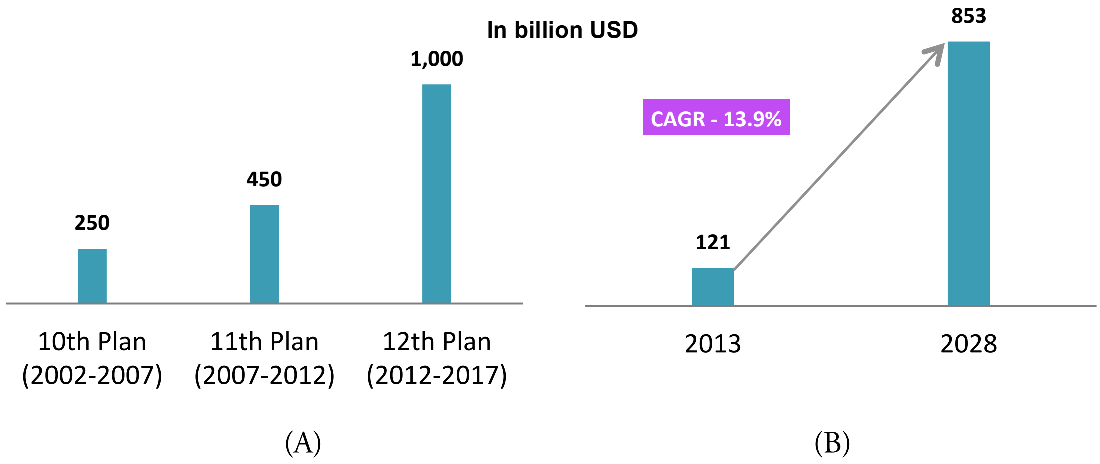


Figure 1: (A) India's Public Spending on Construction; (B) Private Sector Value Addition in Indian Real Estate Sector

Source: (KPMG, 2014)

The construction sector is fuelled by India's rapid urbanisation. Currently, 377 million people live in 7,935 towns and cities (an increase from 5,161 in 2001) across the country which constitutes about 31.2% of the total population. Urban population is expected to be equal to rural population by the year 2039 (Ministry of Housing and Urban Poverty Alleviation, 2011). It is estimated that by 2030, India will have 68 cities with a population of more than one million, 13 cities with more than 4 million people and 6 megacities with populations of 10 million or more (Mckinsey Global Institute, 2010).

This trend of urban population growth will increase the need for buildings, especially residential housing across all classes of towns. The current urban affordable housing deficit already stands at 18.78 million units (Ministry of Housing and Urban Poverty Alleviation, 2012), and is expected to reach 38 million units by 2030 (Mckinsey Global Institute, 2010). The overall residential built-up demand in 2030 is expected to increase over four fold from 2005 (Figure 2).

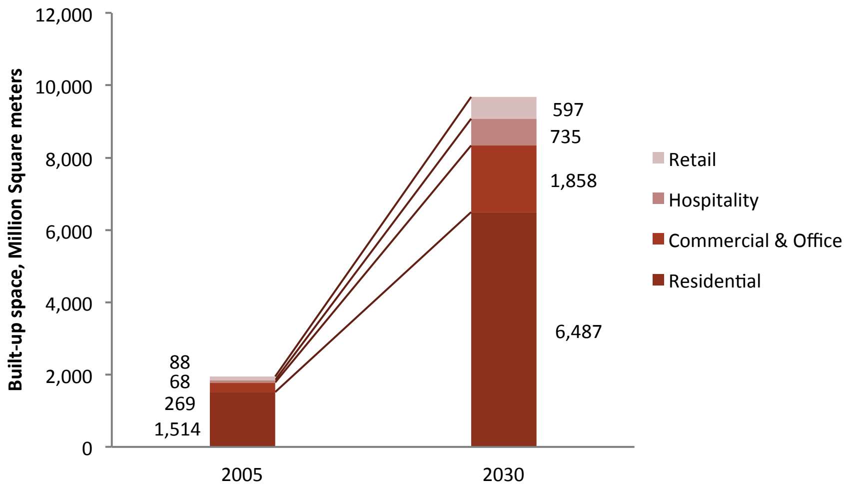


Figure 2: Demand Projection of Built-up Area in India
Source: (Climate Works Foundation, 2010)

The increase in urban population, urbanisation rate, along with purchasing power of individuals increases the demand for housing, which in turn increases the demand for resources required to construct the housing units.

1.3. Resource Use in Construction

The construction sector is resource and energy intensive, accounting for 30% of national electricity consumption and 23.6% of national greenhouse gas emissions (Planning Commission, 2014), 80% of which comes from materials likes cement, bricks, steel and lime (Reddy & Jagdish, 2003). It was the second largest sector in India with regard to material consumption in 2007, accounting for around 20% of all material demand, growing by over one billion tonnes from 1997 (SERI, 2012). The construction sector has strong linkages with other industries, such as cement, steel, chemicals, paints, tiles, and fixtures manufacture. It is estimated that 40–45% of India's steel, 85% of paint production, 65–70% of glass, and significant portions of the output from automotive, mining and excavation equipment industries are used in the construction industry (Planning Commission, 2012).

Construction also accounts for nearly 60–80% of the project cost. Construction materials such as cement and steel, bricks and tiles, sand and aggregates, fixtures, fittings, paints and chemicals, petrol and other petro-products, timber, minerals, aluminium, glass and plastics account for nearly two-third of construction costs (Planning Commission, 2012). Construction materials and equipment production is growing at the rate of 9.8% annually (Darko, et al., 2013). Thus, efficient use of resources is critical for the sector in order to remain economically and environmentally sustainable in the future.

An in-depth look at the elements of a typical urban house highlights the resources used and identifies the important ones (Figure 3). Increasingly, urban construction is moving to RCC (reinforced cement concrete) based frame structures from masonry based load bearing structures. Thus cement and concrete are fast becoming the most sought after construction materials. Cement is composed of limestone with small quantities of other materials such as clay, gypsum and fly ash. The most common type of cement used for construction of residential buildings is fly ash based Portland Pozzolana Cement (PPC). Concrete is a composite material made from a combination of cement, sand and aggregates such as crushed stone. Various proportions of these materials are used to form concrete for different types of structures in a house. Iron and steel bars are used to provide a strong frame for the house.

Masonry is either brick or stone. Bricks are made from top soil and used in foundations, walls, floors, and pavements, etc. of houses. Glass is made from silica and finds its use in windows and doors. Wood is used for frames and shutters. Flooring is either cement based or tile based – ceramic or stone. Common stones include marble and granite, but some regions use other types of locally available stones for flooring and slabs.

Besides structural applications, metal is also used for various other purposes, e.g., copper pipes for plumbing, aluminium for frames, etc. Plastic is however fast replacing them as a cheaper option.

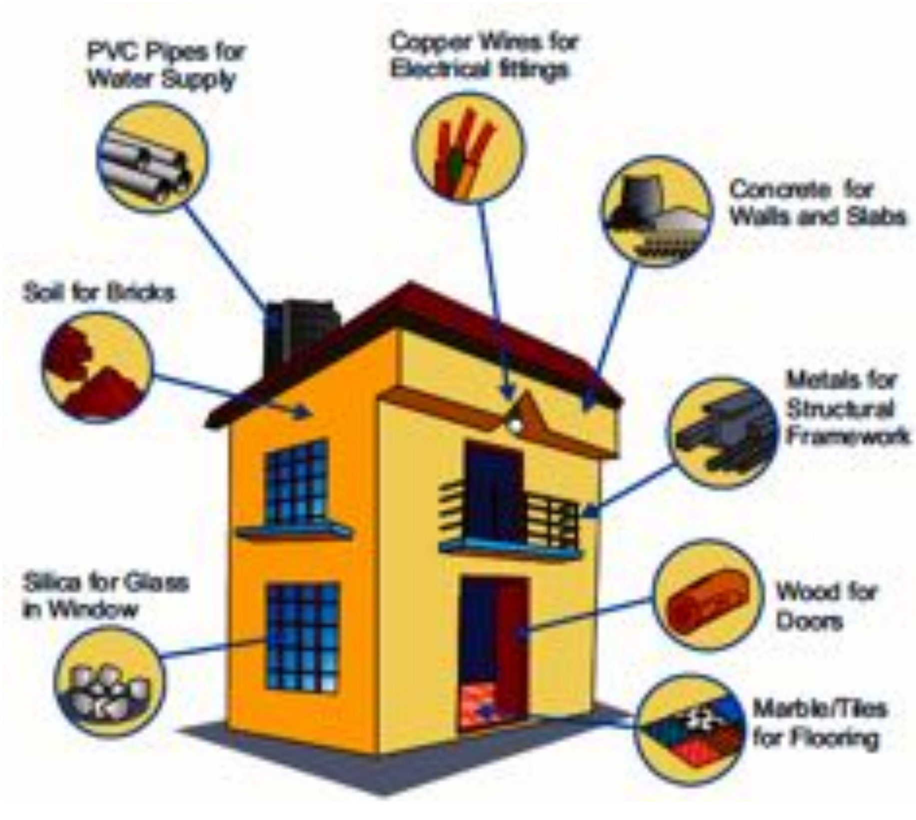


Figure 3: Resources Used in a Typical Urban House

The anticipated increase in demand for these resources will exert added pressure on limited stocks. In order to assess how critical the resources were, a framework was developed and applied to the above resources. A weightage was assigned to each parameter after expert consultations. Available secondary information related to the resource was also studied to give a fair weightage to each resource under the framework. Parameters were also cross-examined against each other to assign weightage. Methodology to assign weightage was similar for each resource to maintain consistency.

Criticality was assessed on the basis of:

- **Scarcity:** This refers to resource use by a building versus its natural availability and ability to be replenished over time.
- **Cost:** This refers to cost of extraction and transit /carriage within Indian geography associated with the resource under the framework.
- **Environmental impact:** This refers to the environmental impact of a resource due to extraction and processing.
- **Embodied energy:** This refers to energy consumed during extraction, production and transport of the resource.
- **Supply risk:** This refers to accessibility of the resource, associated legal restrictions on extraction and transport of the resource, and political risks linked to the resource.
- **Lack of recyclability:** Refers to secondary uses of a resource based on current practices followed by the construction sector.
- **Conflict of use:** Refers to competing uses of a resource by sectors other than construction. For example, soil has two competing uses, brick manufacturing for construction and agriculture.

Table 1: Criticality Framework for Resources Used in the Indian Construction Sector

PARAMETERS → RESOURCE ↓	SCARCITY	COST	ENVIRON-MENTAL IMPACT	EMBODIED ENERGY	SUPPLY RISK	LACK OF RECYCLA-BILITY	CONFLICT OF USE
SOIL	**	*	***	***	**	***	***
IRON	*	***	***	***	*	*	*
LIMESTONE	*	**	***	***	*	***	**
SAND	***	**	***	**	***	***	*
STONE (AGGREGATE)	**	**	***	***	**	***	**
COPPER	*	**	***	***	*	*	*
BAUXITE (ALUMINIUM)	*	**	***	***	*	*	*
PETROLEUM (PVC)	*	**	***	***	*	*	*
SILICA (GLASS)	*	**	***	**	*	*	*
WOOD	**	***	***	**	**	*	*

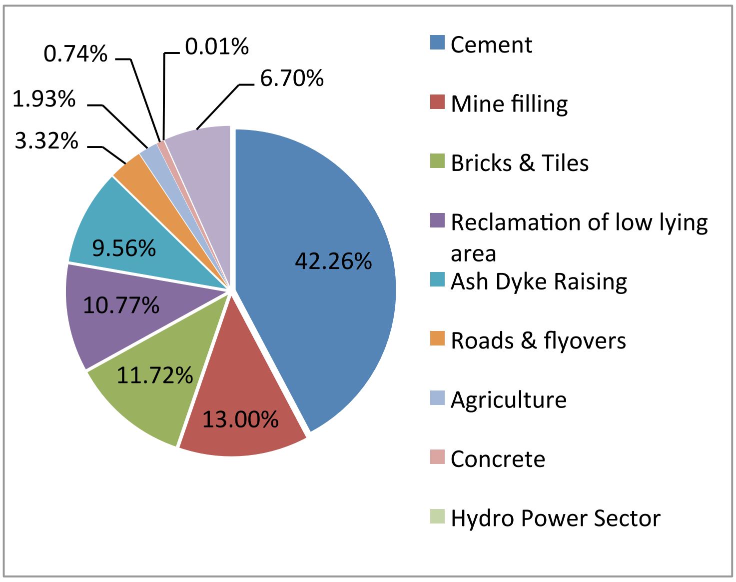
(Legend: *Low **Medium ***High)

Criticality was assessed based on seven parameters. Low, medium or high weightage was given to each parameter represented by the symbol (*). 'Lack of recyclability' was a key distinguishing factor in selecting a critical resource as it has a high impact on the probability of a resource being landfilled as C&D waste. In the context of this report, alternatives were evaluated that can replace or reduce the use of selected critical materials. Soil, Limestone, Sand and Stone (Aggregate) scored high (***) on 3 out of 7 parameters and were selected as critical resources. Iron also scored similarly but was not included in the critical resources since almost all the iron that comes out as C&D waste is recovered and recycled and therefore 'Lack of recyclability' of iron was weighted as 'Low'(*) in the criticality index.

Soil

Figure 4: Modes of Utilisation of Fly Ash in India

Source: (Central Electricity Authority, 2015)



Soil is used in brick production. As the world's second largest brick producer, India annually produces close to 200 billion bricks in over 150,000 small to medium kilns (Maithel, 2012). An estimated 350,000 million tonnes of brick-earth is burnt to meet this demand. Additionally, this soil is a major source of revenue for the state. Brick-earth contributed 5.2% to the value of minor minerals in the year 2014-2015 (Ministry of Mines, 2015).

Fertile top soil, mostly alluvial, is used to make good quality red bricks. Alluvial soils are by far the largest and the most important soil group in India. Covering about 1.5 million km^2 or about 45.6% of the total land area of the country, these soils contribute the largest share of our agricultural wealth (Negi, 2015). Soil extraction for brick production results in denuding 175,000 km^2 land every year[2]. Increased urbanisation leading to an excessive exploitation of top soil for brick making has resulted in decreasing agricultural productivity as well as land and social conflicts due to increased food security concerns (Down to Earth, 2015).

Thus there is a need to explore alternatives to substitute burnt clay bricks. Fly ash bricks are one such alternative, currently occupying 5-7% of the market (Central Electricity Authority, 2015).

Growth in electricity generation, especially coal based power, has led to progressive increases in the generation of fly ash over the last four decades. In 2014-15, 145 thermal power plants with a combined installed capacity of 139 GigaWatts produced 184 million tonnes of fly ash. Of this, 55.69% was utilised in various sectors (Central Electricity Authority, 2015). Fly ash is increasingly being seen as a profitable resource material rather than a waste or useless by-product.

[2] Authors' calculations

Fly ash is particularly suited for use in the construction sector. The use of fly ash in cement is the prime method of utilisation in India. 42.26% of fly ash was used for cement production in 2014-15. The brick sector is the third largest consumer of fly ash at 11.72% (Central Electricity Authority, 2015)

Fly ash bricks are a suitable alternative to the conventional clay based building materials. Usually, they are made from fly ash, lime and gypsum or cement. They can have high compressive strength from 35 to 350 kg/cm^2 and low water absorption capacity (15 – 20%) (Bureau of Indian Standards, 2002). In absolute numbers, the utilisation of fly ash has increased from 0.7 million tonnes in 1998-99 to 11.72 million tonnes in 2014-15 (Central Electricity Authority, 2015). The major fly ash brick producing areas are Maharashtra, Chhattisgarh, West Bengal, Andhra Pradesh, Tamil Nadu, Delhi, Odisha and Bihar. Following the 2009 notification of the Ministry of Environment, Forest and Climate Change on fly ash (S.O. 2804 (E)), if 20% of fly ash is used for brick and tile manufacturing, approximately 23 billion bricks can be produced in the country. This can replace 12% of red bricks[3].

Sand

Sand is another minor mineral critical to construction. It is extensively used for plastering and concreting. Sand contributed 16.5% to the value of minor minerals in 2014-2015 (Ministry of Mines, 2015). The demand is expected to more than double by 2020 to reach 1.4 billion tonnes (Figure 5).

It is primarily river sand that is used for construction purposes and the mining of this sand has tremendous deleterious impacts. The Supreme Court recently warned that riparian sand mining is undermining bridges, disrupting ecosystems, and harming wildlife all over the country. Stripping the river bed leads to downstream erosion, causing changes in channel bed and habitat type, as well as the deepening of rivers and estuaries, and the enlargement of river mouths. As the hydrological system is altered, local groundwater is affected, which leads to water scarcities affecting agriculture and local livelihoods (Beiser, 2015).

Increasing demand due to the construction boom, coupled with easy availability and limited government oversight has given rise to a thriving illegal trade in sand. The annual turnover from illegal sand mining in India is estimated to be INR 10 billion (USD 150 million) (CSE, 2012). Illegal mining has forced several state governments and the National Green Tribunal to impose bans on sand mining and issue warnings to certain states. Sand mining in the river Yamuna flowing in the state of Uttar Pradesh was recently banned by NGT due to obstruction of river flows by sand miners (Indian Express, 2015). Such bans have created a demand and supply gap, resulting in price spikes and often a thriving black market.

This has forced consumers to look for alternatives. However, recycled, secondary and other aggregates currently represent only 3% of all aggregates sales. But this segment is growing at a rapid pace, increasing 7% per annum from 2005 to 2010 (The Freedonia Group, 2013).

[3] Authors' calculation

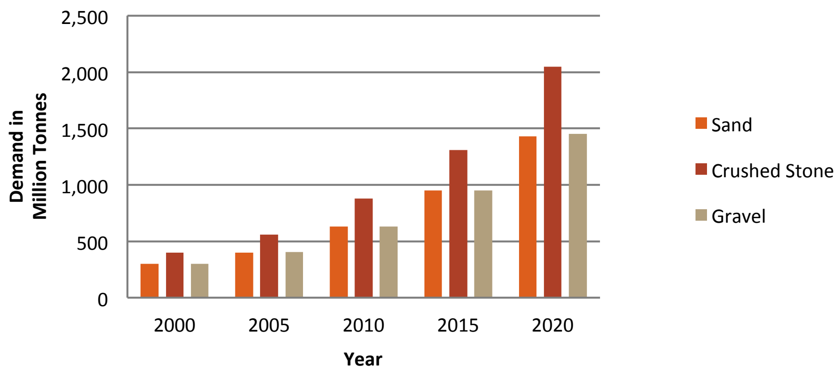


Figure 5: Projected Demand for Aggregates in the Indian Construction Sector
Source: (The Freedonia Group, 2013)

Stone

While stone is used in masonry, its most common application is as crushed stone aggregate. It is typically produced by mining rock deposits and breaking it down to the desired size using crushers. Stone crushing is an extensive industry in India with over 12,000 units across the country (Central Pollution Control Board, 2009). As the most common type of aggregate used in construction, the demand in 2015 was estimated at 1.3 billion tonnes, which was expected to increase to 2 billion tonnes by the year 2020 (The Freedonia Group, 2013) (Figure 5). With the industry slowly moving toward m-sand[4] to combat river sand scarcity, the pressure on stone quarries is bound to increase.

As with all mining operations, stone quarrying is also plagued with environmental issues ranging from noise and air pollution to land and water degradation. Instances of illegal activity in terms of flouting permits and licenses and ignoring environmental standards has led the judicial system to ban stone mining in many areas of the country (Times of India, 2015). Similar to sand and soil (brick-earth), stone quarrying and crushing is also dominated by small and medium industries which are typically unorganized, informal and disaggregated. This makes implementation of legal measures difficult.

Limestone

Limestone assumes importance as the major component of cement. About 95% of the total production of limestone is used for cement (Indian Bureau of Mines, 2014). Cement production is expected to increase from 358 million tonnes in 2010-2011 to 812 million tonnes (High Demand Case) by 2020 (Figure 6). Of this, about 50% is used for housing (National Skill Development Corporation, 2009).

While abundantly available currently, the huge jump in cement consumption is expected to exert some pressure on these reserves. With limestone deposits increasingly falling under eco-sensitive

[4] Manufactured sand made from finely crushing stone

zones, the impacts of uncontrolled mining frequently results in polluted air, reduced forest cover and opposition from local communities. Aligned with the GDP, the 10% projected annual growth in cement consumption would mean about 600 million tonnes per annum of limestone demand by 2020 or roughly double the present capacity of about 300 million tonnes per annum (Indian Bureau of Mines, 2014). In such a case, limestone availability for the cement industry is not assured beyond 50 years (FICCI Mines and Metals Division, 2013).

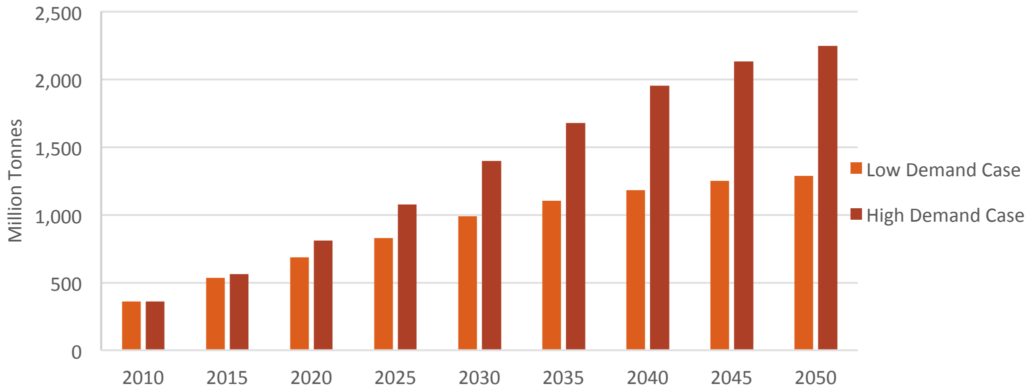


Figure 6: Projected Demand of Cement in India

Source: (Indo-German Environment Partnership, 2013)

Cement production is also linked to greenhouse gas (GHG) emissions, especially carbon dioxide (CO_2) emissions. Total emissions of CO_2 reported by Indian cement companies in the year 2013 was 66 million tonnes, which is about 12% of total CO_2 emissions reported by cement companies around the globe in the same year (Cement Sustainability Initiative, 2015). Another cause of concern is the energy intensity of cement production. This makes it vital to explore alternatives. Blended cements reduce the percentage of limestone based clinker with substitutes like fly ash, slag and calcined clay. While fly ash based cements have broken market barriers and now occupy majority market share (Central Electricity Authority, 2015), the others are still overcoming technical and market challenges.

1.4. Importance of Resource Efficiency in Construction

The critical resources used by the construction sector are finite and take a long time to replenish. Currently, per capita consumption of materials in India is around 1.5 tonnes, which is a remarkable fivefold increase since 1980. It has been estimated that the construction sector will have the highest levels of material consumption in India within a decade if current trends continue (Indo-German Environment Partnership, 2013). Over 70% of the buildings required in India by 2030 are yet to be built (NRDC-ASCI-Shakti, 2012). This is a huge responsibility for preventing a lock in of resource intensive investments and presents a tremendous opportunity for decoupling critical resources from environmental impact and economic benefits through resource efficiency (Figure 7).

Resource Decoupling promotes using less material for the same economic output thus seeking to alleviate the problem of scarcity by reducing the rate of physical resource depletion, while simultaneously helping to reduce costs by raising resource productivity.

Impact decoupling looks at raising economic output while reducing negative environmental impacts that arise from the extraction of required resources.

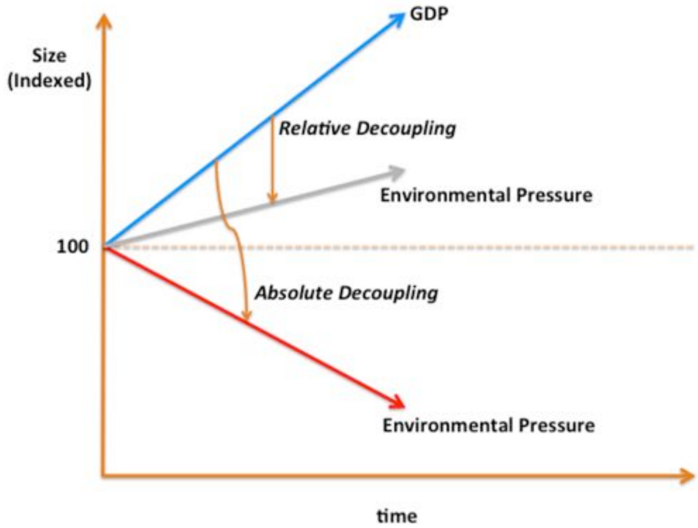


Figure 7: Decoupling for Resource Efficiency

Source: (Indo German Expert Group on Green and Inclusive Economy, 2014)

Use of secondary raw materials is a viable approach to achieving resource efficiency of critical building materials by decoupling. A secondary raw material can be waste from another industry or an alternate material available in nature that can be used in place of a critical resource. Table 2 presents a summary of secondary raw materials that can replace some critical primary resources discussed above.

Table 2: Use of Secondary Raw Materials in Construction

PRIMARY RESOURCE	SECONDARY RAW MATERIAL	SOURCE	APPLICATION
SOIL	• Fly ash • Industrial wastes like marble sludge	• Thermal power plants • Industries	• Fly ash bricks • Alternates / waste based bricks
STONE	• Demolition waste	• C&D waste	• Recycled aggregate • Replacement in asphalt mixtures, Portland cement concrete.
SAND	• Demolition waste • Natural stone	• Construction Sites • Quarry	• M-sand
LIMESTONE	• Crushed limestone • Calcined clay • Fly ash • Slag	• Low quality limestone • Overburden from clay mines • Thermal power plants • Sponge iron Industries	• Blended cements

C&D waste is inert and bulky in nature and is typically dumped in the open in India after segregating valuable materials such as wood, iron and steel, aluminium, etc. Studies have shown that materials left after segregating such valuables also have a potential to be used as a resource in various construction applications. The further sections of this report attempt to analyse C&D waste generation in India and its techno-economic feasibility to be used as secondary raw material in the construction sector.

Chapter 2: Construction & Demolition Waste: Generation and Characterisation in India

2.1. Construction & Demolition Waste Generation

Construction and Demolition (C&D) waste is defined as '*Waste comprising of building materials, debris & rubble resulting from construction, re-modeling, repair & demolition of any civil structure*' (Draft Solid Waste Management Rules) (MoEF&CC, 2015). Literally all material waste coming out of the construction and demolition industry is considered as C&D waste.

Table 3: C&D Waste Generation in Different Countries

COUNTRY	GENERATION (Million Tonnes/ Annum)	PER CAPITA GENERATION (Tonnes/ Capita)[5]	YEAR
China	2,190	1.63	2011
(Lu, 2014)			
EU-27	461	0.94	2005
(European Commission (DG ENV), 2011)			
India	530	0.423	2013
(CSE, 2014)			
USA	170	0.585	2003
(Calkin, 2009)			
Japan	123	1.04	2007
(Zimring, 2014)			
England	100	1.573	2012
(DEFRA, 2015)			
Dubai	27	0.06	2007
(bizzwhizzdubai, 2008)			

Studies from all around the world show that C&D waste occupies a substantial portion of the solid waste stream. In North America, it accounts for 25 – 40% of the total MSW generated (Tabsh & Abdelfatah, 2009). In developed countries, the average annual per capita C&D waste generation is 500 – 1,000 kg (Nitivattananon & Borongon, 2007). However, developed and developing countries alike produce huge quantities of C&D waste (Table 3); the rate of generation increasing along with development of the construction sector. A case in point, Dubai saw a record growth in C&D waste generation of 163% in just one year (2007) (Shrivastava & Chini, 2009).

Like many other developing countries, India also generates huge quantities of C&D waste each year. In 2001, the Technology Information, Forecasting and Assessment Council (TIFAC) estimated[6] the national annual C&D waste generation to be around 12 to 14.7 million tonnes. TIFAC estimated that demolition generates an average of 300-500 kg waste per m^2 of construction; new construction generates 40-60 kg waste per m^2 and renovation generates 40-50 kg waste per m^2 (TIFAC, 2001).

[5] All population data has been sourced from data.wordbank.org
[6] C&D waste was estimated to be 25% of the total Municipal Solid Waste (MSW) generated.

Based on these thumb rules, in 2013, the Centre for Science and Environment (CSE) estimated[7] total C&D waste generation in India at 530 million tonnes (CSE, 2014). Per capita C&D waste generation was estimated at 10 kg per annum (CSE, 2013). The current study estimates the annual C&D waste generation in 2015 to be 716 million tonnes. The estimation methodology and findings are discussed in detail later in this chapter.

The Indian construction sector accounted for approximately 50% of the country's capital outlay in the 9th and 10th Five Year Plans (Ghosh, 2011). With the anticipated growth in the sector over the next plan period, as seen in the previous chapter, the associated C&D waste generation is also expected to increase several fold. Extrapolating data as per expected urban population growth, it would appear that India will generate approximately 2.7 billion tonnes of C&D waste annually by 2041 (Figure 11). This figure is calculated on the basis of data collected from 10 cities as part of the survey described in section 2.2.

Characterisation studies on C&D waste in India are minimal since it is usually collected and mixed with MSW. TIFAC's waste characterisation study highlighted soil, sand and gravel (fines); brick and masonry, and concrete as the three largest fractions accounting for 90% of the waste (TIFAC, 2001). Similar studies were carried out in Delhi (IL&FS Ecosmart, 2005) and Coimbatore (CCMC, 2015), with the bulky materials jointly found to occupy 90% and 91% respectively (Figure 8). The remaining 10% comprises of wood, metal, bitumen, plastics, etc.

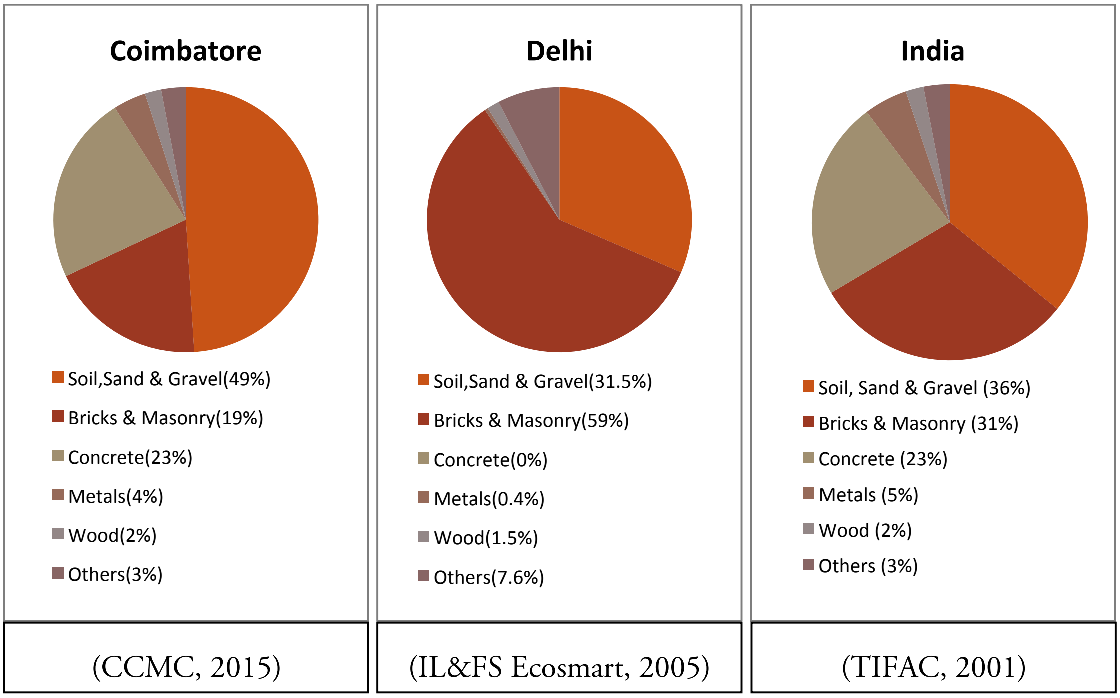


Figure 8: Different C&D Waste Characterisation Studies in India

[7] C&D waste was calculated on the basis of TIFAC's thumb rules on waste generation during construction, renovation and demolition. CSE found 1 billion m^2 of new construction in 2013, and assumed 5% of the entire existing building stock was demolished and one third underwent some sort of repair or renovation.

2.2. Construction & Demolition Waste Estimation Methodology

Quantification of C&D waste is essential to plan and implement a proper management system. Few comprehensive attempts have been made in India before to estimate and characterise C&D waste, the most cited study (TIFAC, 2001) being more than 15 years old. The lack of a universally accepted or government authorised survey methodology necessitates that studies evolve their own methodologies and tools for data collection. Some of the common methodologies applied in developed counties include:

- Site Visit Measurement: Measurement of segregated waste at sight by visual inspection, observing number of truck loads, etc. (Lau, Whyte, & Law, 2008).
- Waste Generation Rate Method: Based on material value during construction, material wasted during construction, per-capita multiplication indices and area of building constructed or demolished (McBean & Fortin, 1993).
- Lifetime Analysis Method: Based on lifetime of individual materials used for construction and that of buildings (Wu, Yu, Shen, & Liu, 2014).
- Classification System Accumulation Method: Based on site visits, financial value extrapolation and area-based calculation (Jaillon, Poon, & Chiang, 2009).
- Variable Modelling Methods: Prediction using modelling based on relation between variables; e.g. – economic indicators, on-site working conditions, etc. (Wimalasena, Ruwanpura, & Hettiaratchi, 2010).

The above mentioned methodologies could not be applied in the Indian context due to limitations in data availability and difference in waste management practices in India. C&D waste is not segregated and transported as a whole; the informal sector plays a large role in this process; there is no documentation of waste removed from demolition sites. Also, data required for methodologies which include lifetime analysis, economic indicators, or area wise construction data is inadequate or inaccessible. Most ULBs maintain annual documents stored in a decentralised manner at different zones or wards and hence retrieving of data becomes time consuming and challenging for a study of short duration.

Hence it was very important that an appropriate methodology be derived for the quantification and characterisation of C&D waste. This analysis used an iterative process involving secondary literature and primary research, which was extrapolated to develop a national scenario. Data collection was undertaken through site visits and interactions with various public and private stakeholders - ULBs, major builders (government/private), demolition contractors, and waste processing units. Semi-structured interviews were conducted with different public and private sector stakeholders. Stakeholders were questioned on the following aspects:

- Status and patterns of construction and demolition and C&D waste generation in cities (impacts of seasonal variation, age of buildings, construction practices, prevalence of alternate materials, etc.)
- Demolition techniques and practices followed
- C&D waste management system (approvals from ULB for demolition, segregation, transportation and process flow of materials, initiatives taken by ULB on processing of waste)

A sample set of ten cities was used to identify the existing situation of CDW generation, management and flow of materials in India. The focus was on Mega[8] and Tier 1 Cities[9]. They were selected to achieve a geographic spread spanning the entire country, narrowing down based on potential determined by investment promised to the region and interest of stakeholders in the process (Figure 9). For details of city selection criteria, see Annex 1. The selected cities were:

- ***Metro Cities*** – Mumbai, Delhi, Kolkata, Chennai, Bengaluru (formerly Bangalore)
- ***Tier 1 Cities*** – Patna, Ahmedabad, Jaipur, Coimbatore, Bhopal

Waste generation data was collected from 10 surveyed cities and correlated against urban population and density since accurate city level data was available for both of these parameters. Regression coefficients (R^2 values) were calculated to analyse correlation of C&D waste with population and density of a city.

Urban Population from the base year of 2011 was then projected using geometric method of projection[10]. The urban population projections were then incorporated in the regression equation, calculated from correlation curves to extrapolate C&D waste to national figures for 2015.

To characterise C&D waste, samples were collected from the 10 surveyed cities and analysed for various components. On an average, 3 to 5 C&D waste samples were collected from each city. For details of sampling, see Annex 2.

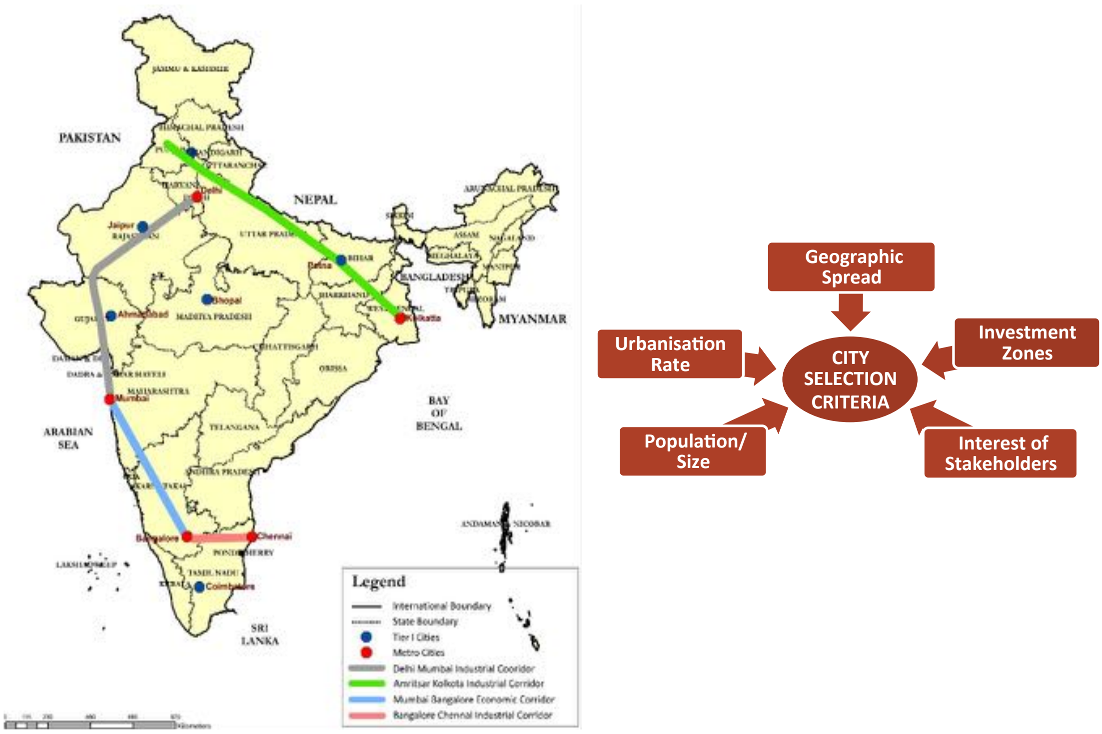


Figure 9: City Selection for C&D Waste Survey

[8] As per Census of India, 2011, cities with 10 million and above population are classified as Mega cities.
[9] As per Census of India, 2011, cities with population 100,000 and above are classified as Tier 1 cities.
[10] Adopted from population projection (2012-2021) done for state of Karnataka by Directorate of Economics and Statistics, Bangalore, 2013.

2.3. Current Trends & Projections

The survey of 10 cities produced C&D waste generation data. Table 4 presents a summary of the results of the survey conducted.

Table 4: Summary of City C&D Waste Generation Data

ULB	POPULATION (CENSUS 2011)	C&D WASTE GENERATION (MILLION TONNES/ANNUM)	C&D WASTE GENERATION (TONNES PER DAY)
Municipal Corporation of Greater Mumbai	12,442,373	0.750	2,500
www.mcgm.gov.in			
Delhi Municipal Corporation	16,787,941	1.380	4,600
(DMC, 2005)			
Greater Bengaluru Municipal Corporation (BBMP)	8,443,675	0.263	875
(TIFAC, 2001)*			
Chennai Municipal Corporation	6,500,000	0.750	2,500
As per discussions with IIT-Madras			
Kolkata Municipal Corporation	4,496,694	0.480	1,600
As per discussions with KMC			
Jaipur Municipal Corporation	3,471,847	0.060	200
(TIFAC, 2001)*			
Patna Municipal Corporation	2,514,590	0.075	250
(TIFAC, 2001)*			
Ahmedabad Municipal Corporation	6,063,047	0.210	700
As per discussions with AMC officials			
Bhopal Municipal Corporation	1,917,051	0.015	50
(TIFAC, 2001)*			
Coimbatore City Municipal Corporation	2,618,940	0.028	92
(CCMC, 2015)			

Source: Authors' Survey

*Due to unavailability of data for these cities, 25% of MSW was taken as C&D waste based on TIFAC, 2001 study

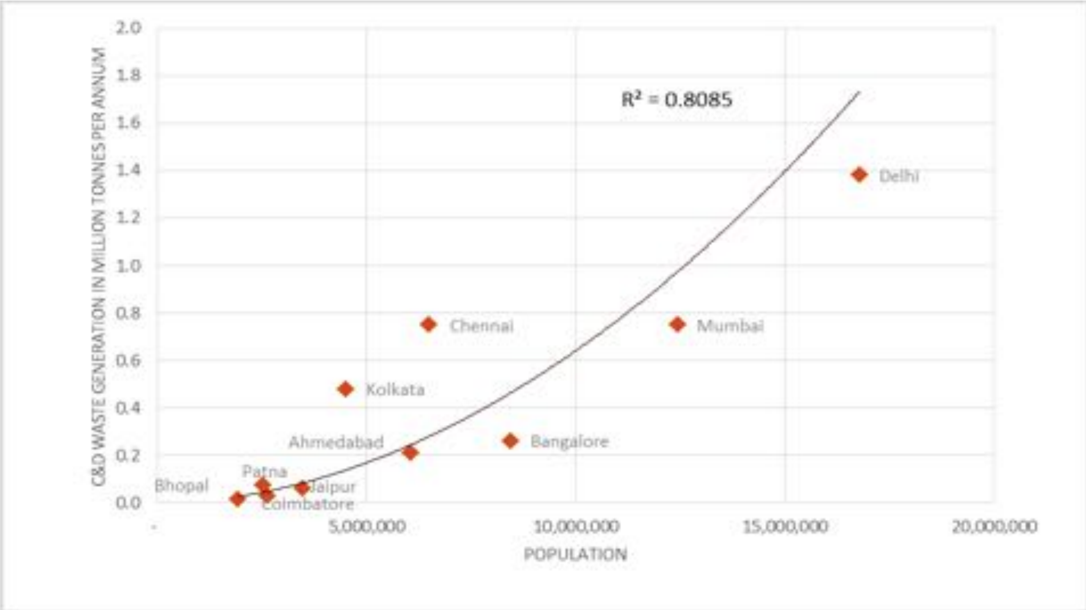


Figure 10: Correlation Between Population and C&D Waste Generation

The correlation between urban population and C&D waste generation is depicted in Figure 10, which seems to show a strong correlation overall. Plausible explanations can be found for many of the outliers based on the survey. In Bengaluru, population is relatively high but C&D waste generation is comparatively low. This can probably be explained by the lack of data available on the C&D waste generated in the city. Hence an estimate of 25%[11] of total MSW generated is used. Conversely, Kolkata has a relatively higher waste generation compared to its population; this may be due to accurate records available on C&D waste disposal in the municipal landfill. Another departure from the trend is Chennai. The recorded waste generated here is 2,500 tonnes per day, as high as Mumbai. This can be attributed to the fact that currently a detailed study is underway in Chennai, hence more than usual data is being collected. Unlike other places where estimates are based on data collected (or estimated) for final disposal, the Chennai estimate is based on actual generation potential. Thus it is evident that the type and authenticity of data collected is very important to derive a reliable final figure.

As there was a very high correlation between urban population and C&D waste generation, a scenario where urban population grows geometrically (based on decadal urban population growth figures from the 2011 census) was used to project C&D waste generation in India. The results show urban C&D waste generation in 2015 as 716 million tonnes, which is expected to increase to 2.7 billion tonnes per annum in 2041. The projections are presented in Figure 11 below.

[11] Based on the TIFAC, 2001 study

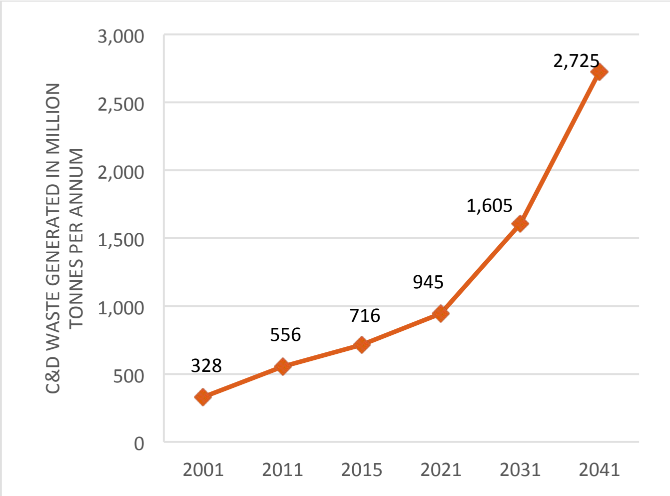


Figure 11: C&D Waste Generation Projection in Urban India (2001-2041)

Though the study found a strong correlation between urban population and C&D waste generation, it is worth acknowledging that C&D waste generation is also influenced by market conditions such as recession or sudden surge in growth of construction sector. As such anomalies are difficult to predict, actual C&D waste generation may be different from projections based solely on population.

For understanding the types and quantities of building materials used, two building types were considered under two different geographical conditions. Thus for calculation, a standard two BHK, single storeyed building was considered in load bearing and frame structures typically adopted in the Northern and Southern parts of India. The main difference between the houses in Northern and Southern parts of India were found to be in the number of windows (Kumar, 2015). Table 5 gives the percentage of materials used in different types of buildings.

Table 5: Percentage of Materials Used in Different Types of Buildings in India

S. NO.	TYPES OF MATERIALS	NORTHERN REGION		SOUTHERN REGION	
		FRAME STRUCTURES	LOAD BEARING STRUCTURES	FRAME STRUCTURES	LOAD BEARING STRUCTURES
1	Bricks	22.74	46.61	21.94	45.36
2	Mortar	17.54	20.33	16.92	20.37
3	Concrete	56.39	31.26	57.63	32.33
4	Steel	2.02	0.93	2.06	0.96
5	Wood	0.26	0.18	0.33	0.22
6	Glass	0.03	0.02	0.09	0.06
7	Ceramic Tiles	1.01	0.68	1.04	0.70

Source: (Kumar, 2015)

Table 5 shows that in frame structures the amount of concrete that can be generated as waste is higher than load bearing houses made with normal burnt clay bricks. Similarly, the amount of bricks used is higher in load bearing structures.

Waste characterisation studies of collected samples reiterated that bulky materials form the majority of the waste generated (Figure 12). Concrete is one of the largest fractions, followed by bricks and sand. Wood, metal and other commodities were not collected as part of the samples as they are segregated at the site and sold in the secondary market almost immediately. Hazardous materials like asbestos and bitumen were not found in the samples. Asbestos sheets found in the roofing of old houses are removed at the demolition site itself and sold in the secondary market.

It should be noted that these samples only give a snapshot of the composition of waste generated. Since samples were collected only once from a particular site, it may not be representative of the entire building. Further, only a limited number of sites were sampled in a limited amount of time; so the findings are not completely representative of the entire city. The characterisation results deviate significantly from the national characterisation studies depicted in Figure 8 for the above mentioned reasons as well as due to demolition practices being followed at the sampled sites. Almost in all the cases, major walling material was (older) burnt clay bricks which were of much higher quality than currently manufactured bricks. These bricks have substantial value in the secondary market. In cities like Ahmedabad, Chennai, Bengaluru and Mumbai, valuable materials including such reusable bricks are removed quickly upon demolition. In the cities in north and east India, contractors are not in a hurry to segregate and remove the waste from the site. These leftover materials were collected from the demolition site. Such local factors influence what kind of waste is left behind for collecting samples. To get a representative picture of characterisation of waste in a city, a more detailed study of much longer duration will be necessary.

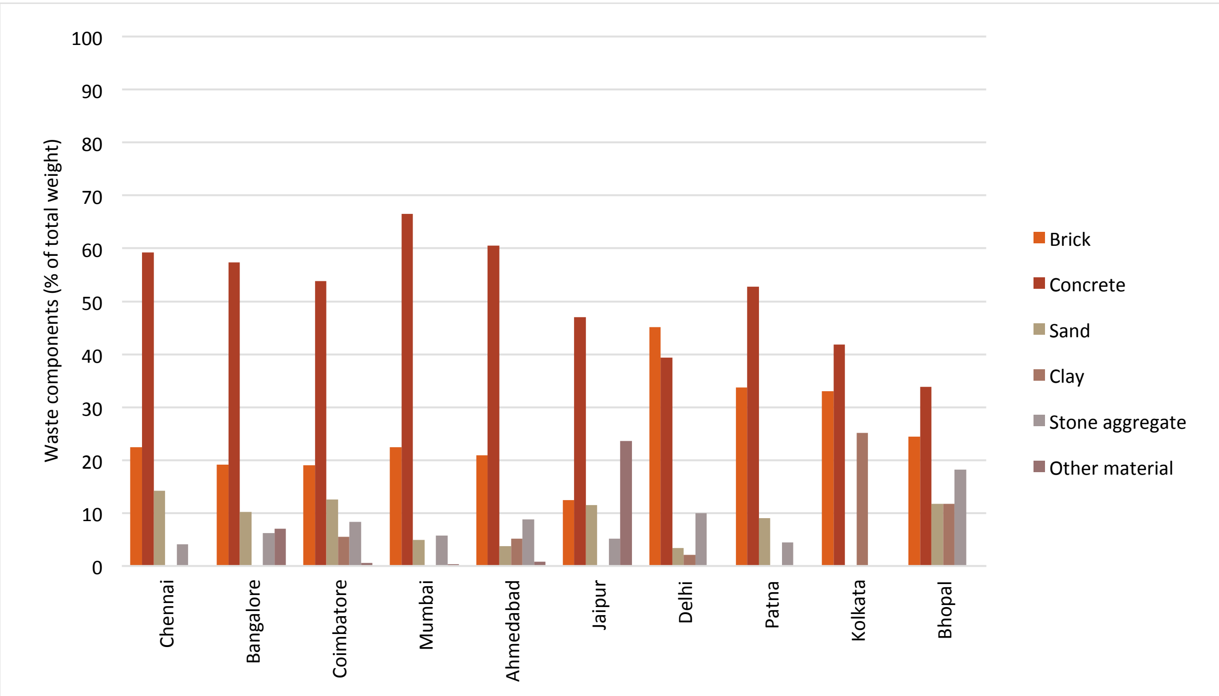


Figure 12: C&D Waste Analysis From Surveyed Cities

2.4. Factors Affecting C&D Waste Generation

The amount and character of C&D waste generated is influenced by a series of factors. Foremost among them are demographic factors such as population, rate of urbanisation, population density and socio-economic status of people. Age of the city, as well as construction and demolition patterns and practices are among other important factors which affect generation of C&D waste. These factors are explored in further detail below.

Demographic Factors

A direct correlation was observed between ***population*** and C&D waste generation. A very high regression (R^2=0.80) was obtained proving a significant correlation.

Tier 1 cities are growing faster than the Metros. Cities with a population between 1 – 4 million are growing at a rate 50% higher than that of 4 million plus cities (Kundu, 2013); thus there is more construction (and demolition) per capita. Thus the ***rate of urbanisation*** seems to have a positive impact on C&D waste generation.

The ***socio-economic status***, especially of the middle class, has a major impact on the construction sector and hence C&D waste generation. As the spending capacity of people increases, investment in construction increases, creating spillovers in C&D waste generation.

Population ***density*** in the cities did not show a significant correlation with C&D waste generation. The varying density in different parts of the city and the legal measures in place are responsible for adding complexity to the equation.

While demography and population of cities show a strong correlation with the generation of C&D waste, they are not the only factors. Other factors like the nature of urbanisation, age of cities and construction practices, among others, also influence generation. India is a vast country with huge difference in geography of land, soil and climate. This difference is also reflected in the construction sector where building materials and construction styles depend on the availability of material and local habitat. C&D waste is also greatly influenced by the construction and demolition practices in place. Factors like styles of construction, patterns of growth, age of the construction, legal measures in place, all play a role.

Pattern of Construction in Cities

The Metros are seen to have denser growth, more high-rise buildings with a penchant for further vertical growth. This is in part driven by the lack of availability of land, either physically or due to prohibitively high land costs. In comparison, Tier 1 and other smaller cities still have the luxury of growing horizontally. The differential skylines of, say, Mumbai versus Jaipur clearly reflect this pattern. Thus the nature and amount of waste generated on demolition of such construction would differ too. The fraction of concrete would go up in case of demolition of frame based structures over load bearing masonry structures. Table 4 provides evidence to this observation.

Building materials used for construction also vary from city to city. Cities like Mumbai, Bengaluru and Coimbatore face shortage of virgin raw materials like sand. Hence, use of m-sand, concrete bricks, fly ash bricks, etc. is prevalent. Fly ash bricks are also being used in other cities like Bhopal, Ahmedabad, Chennai, etc. Use of stones is prevalent in Jaipur. This shift in the use of alternate materials will also have a bearing on the composition of C&D waste in the future.

Age of the City

The ***age of the city*** also contributes to this phenomenon. Older cities are more urbanised and have a larger construction/built up footprint that will need to be renovated or demolished to cope with increasing populations. But newer cities are building up for the first time. In cities like Jaipur, where ***land*** cost is less and more land is available, and in Coimbatore where land is easily available and is easily accessible even in the outskirts due to good infrastructure and connectivity, there are more instances of greenfield construction. Cities like Mumbai where land costs are high and the opportunity cost of building in the outskirts is too high, see more demolition of older buildings for reconstruction. Also, mandatory demolition laws exist in some cities for buildings over a certain age (60 years in Jaipur and Mumbai). Thus the quantum of C&D waste will be higher in older cities.

The exception of course is where certain cities decide to go the ***conservation*** route. Kolkata promotes restoration and renovation over demolition. Thus the waste generation is less even though it is a densely constructed older Metro. Most old cities (Metros and Tier 1) have certain zones that are conserved for heritage reasons and kept safe from demolition. However, this rarely extends to the majority of the built footprint of the city.

Change in FSI/FAR

Another factor that influences C&D waste generation is the ***master plan*** and incentives like enhanced ***FSI/ FAR***. In order to spur growth, additional FSI is declared for certain zones, for example proposed Metro lines, highways (transport corridors), etc., thus encouraging denser vertical growth. This has a direct impact in terms of increased reconstruction in these areas, directly contributing to more C&D waste generation. Delhi for example, recently raised the FSI from 2.5 to 4 (Business Standard, 2015). Chennai has also pursued FSI relaxations for cluster development. Over 15 cities that have (proposed) Metro lines are expecting similar relaxations.

Demolition Practices

Demolition practices and ***reuse*** of material in the construction and allied sectors also impact the quantum of C&D waste in a city. Demolition by machinery is prevalent in southern parts of the country like Chennai, Coimbatore, Bengaluru and Mumbai. Minimal attempt is made to retrieve whole bricks due to their poor quality. Demolition activities are also time bound giving demolition contractors less time to recover materials. On the other hand, whole bricks are removed in cities in northern parts of the country like Patna, Kolkata, etc. Superior quality bricks in the Indo-Gangetic plains and relatively low labour costs are some of the reasons for manual demolition in these regions.

In most cities, only valuable materials like metal and wood are reused whereas a major portion of the debris generated is considered waste. However, in Jaipur it was observed that most material including stone, rock and concrete slabs are reused, which reduces the waste part to only the relatively smaller fraction of concrete and broken stones. Valuable materials are sold in the secondary market by the demolition contractors for reuse in the sector. In many cities, even the residual waste is used as filler material for new construction sites, but since this practice is unregulated, it is impossible to estimate the amounts thus diverted. Such reuse practices help reduce the C&D waste footprint of the city.

Table 6: Cost of Recovered C&D Waste Materials in Secondary Market

CITY	COST OF BRICKS (INR)	COST OF WOODEN FRAMES (INR)	COST OF METAL (INR)	COST OF DEMOLITION DEBRIS (INR)
CHENNAI	1 per brick	200 – 1,000 per frame	5 – 10 per kg	2,000 per truck load
COIMBATORE	--	500 – 2,000 per frame	5 – 10 per kg	1,000 per truck load
BENGALURU	1 per brick	500 – 3,000 per frame	10 – 12 per kg	2,000 per truck load
MUMBAI	1,000 – 2,000 per truck	5,000 – 10,000 per frame	30 per kg	--
AHMEDABAD	--	2,000 – 3,000 per frame	15 – 20 per kg	1,000 per truck load
PATNA	4 – 5 per brick	4,000 – 6,000 per window frame 2,000 – 3,000 per door frame	--	
JAIPUR	2 per brick	300 – 500 per frame	20 – 25 per kg	1,000 per truck load
BHOPAL	--	2,000 – 3,000 per frame	30 – 45 per kg	1,000 per truck load
KOLKATA	4 – 5 per brick	5,000 – 6,000 per frame	25 per kg	--

Source: Authors' Survey (USD 1 = approx. INR 65)

C&D Waste Management Strategies

C&D waste management strategies exist in Delhi and Ahmedabad. Processing facilities have been set up in collaboration with private entities. Proper collection and transportation systems have been set up to aid processing. Illegal dumping practices are also discouraged due to penalties on open dumping. As a result, an increase in the amount of C&D waste recorded and managed can be seen. Chennai and Kolkata are some exceptions to unaccounted C&D waste generation. Kolkata keeps records of the amount of C&D waste getting dumped in landfills. Chennai is the only city which gives demolition permits to waste generators as compared to reconstruction permits given in other cities. This facilitates the calculation of C&D waste generated on the basis of area and type of buildings demolished.

Chapter 3: Construction and Demolition Waste Management in India

3.1. C&D Waste Management in India

Building demolition, a common sight in cities and growing towns, is a natural consequence of increasing urbanisation with limited land resources. Buildings could be demolished voluntarily for renovation, alteration and/or reconstruction for vertical development. Sometimes, they are demolished if they violate building bye-laws and permits. Old buildings considered hazardous by Urban Local Bodies (ULB) are also demolished to prevent collapse and risk to public safety. However, efforts to manage the waste are minimal. Figure 13 illustrates the process of management of waste in different cities in the country.

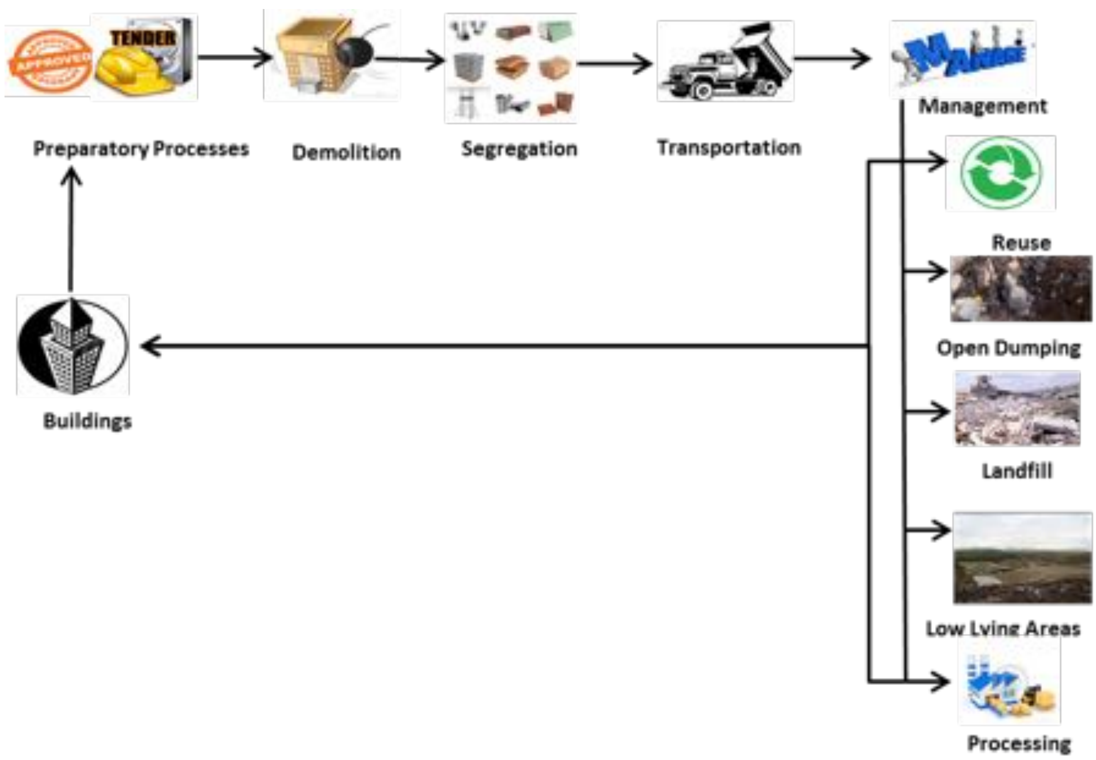


Figure 13: Schematic of C&D Waste Management Processes in India

Preparatory Processes

Preparatory processes include activities carried out after the intent to demolish a building has been established. The first step is to obtain ***approvals from the ULB***. Chennai Municipal Corporation issues demolition permits to construction/demolition contractors. However, they are one of the few ULBS that do so; hence they also have a better record of the demolition waste generated. While the Coimbatore City Municipal Corporation doesn't issue demolition permits, they collect demolition waste handling fees (INR 500 per 100 ft^3) from the generator at the time of issuing reconstruction permits.

Most ULBs issue reconstruction approvals that also account for demolition. In case of reconstruction or alterations, developers need to apply for sanction and submit revised building plans to the ULB. For example, in Kolkata, every person who intends to erect a new building on any site, whether previously built upon or not, or re-erect or make addition to or alteration of any building, has to apply for sanction by giving notice in writing to the Municipal Commissioner. In case of mandatory demolition, ULBs issue notices to building owners before demolition. The Kolkata Municipal Corporation (KMC) serves Stop Work notices after detecting illegal construction and deals with it under section 400 (I) or 400 (8) of KMC Act 1980.

The Construction and Demolition and Desilting Waste (Management and Handling) Rules, 2006 require the generator to apply for permission and submit a waste management plan; but implementation has been poor. The Draft Solid Waste Management Rules 2015 by MoEF&CC aims to remedy this common problem by insisting generators obtain permission from ULBs and submit a waste management plan.

After obtaining due permissions from the ULB, Government Departments like the Public Works (PWD) prepare ***tenders and invite bids for demolition***. The bids are calculated on the basis of cost of recyclable materials like steel, door and window frames, RCC work, and brick work in a building. The assignment of demolition is awarded to the highest bidder. In most cases, contractors pay the departments for demolition and removal of waste from the site.

Private developers contact independent contractors for demolition. In these cases, the developers may pay for availing the services of the contractors. The contractor is responsible for demolition and disposal of waste generated. Depending on whether the actors are public or private, the cash flows change direction.

Demolition

Contractors are allotted a fixed duration of time to demolish a building and remove the waste from the site as per their tender or contract. Buildings can be demolished either manually or mechanically after the removal of door and window frames (Figure 14). Regional differences on the methods of demolition have been observed. Manual demolition by hammers and pickaxe is the norm in northern India. This investment in terms of time and labour is made primarily due to the higher rates of reuse of building materials, especially good quality whole bricks. The presence of a profitable secondary market for recycled materials and low labour rates encourages contractors to demolish manually.

Mechanised demolition by pneumatic machinery like concrete breakers and heavy machinery like wrecking balls is observed in western and southern India. Time constraints and high labour costs force contractors to demolish by machinery in cities like Chennai, Mumbai and Ahmedabad. Also, the quality of bricks in older buildings in these regions is inferior compared to northern India, hence demand from the secondary market is not an important factor to be considered.

Figure 14: Demolition of Buildings

Segregation

C&D waste is segregated at site by demolition contractors and informal sector waste dealers. The waste is segregated manually in the following streams:

- Door and window frames (wood)
- Steel rods (metal)
- Whole bricks
- Concrete/broken bricks/lime mortar debris
- Plastics/ceramics

(A)

(B)

Figure 15: (A) Segregation of Whole Bricks on Site; (B) Illegal Dumping on the Road

Bricks are collected and cleaned for reuse on site or resale wherever possible. However, they form a part of the debris when buildings are demolished by mechanised means. The valuable materials are either picked up by the informal sector or sold off in the secondary market for reuse in construction by the demolition contractors. The remaining debris is dumped in open or low-lying areas or sometimes in ULB designated dump yards by the transporters (Figure 15).

ULBs have so far are not able to provide proper collection, disposal and management systems for C&D waste in most cities. Informal sector waste dealers contribute significantly to waste management by collecting, sorting and segregating the waste at site. They remove valuable commodities either for their own use or for selling in the secondary market. These activities are a source of income to this sector.

Transportation

C&D waste is transported from the site by trucks or tractors to disposal sites by paying a minimal fee to the transporters. These transporters can be private or empanelled with the ULB. The responsibility of transporting waste in cities like Chennai lies with the waste generator. They are required to deliver the C&D waste at their own expense to the two designated dumpsites (Perungudi and Kondungaiyur) owned by the Municipal Corporation. Delhi has a relatively elaborate system of collection (see Annex 4) with 168 collection points where C&D waste can be dumped by the generators. The ULB transports the waste to the disposal site from these points or contracts with private contractors to do so.

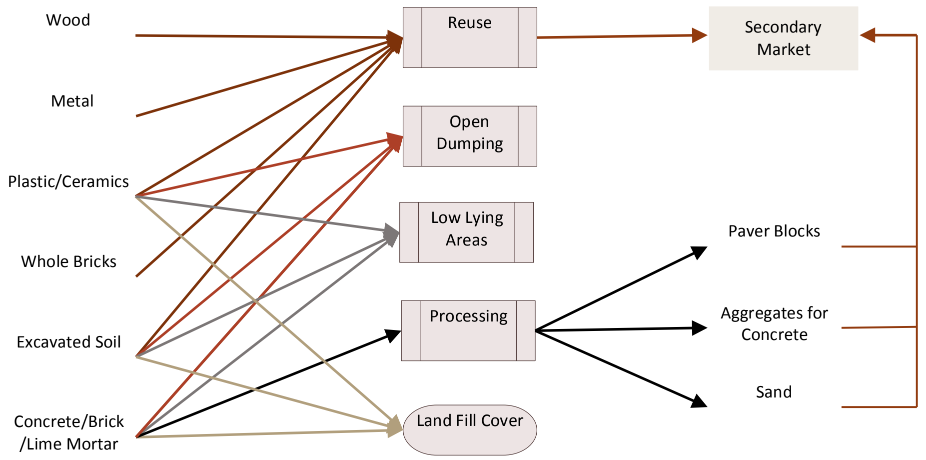


Figure 16: Material Flow from C&D Waste in India

Management

Currently, C&D waste is considered a part of municipal solid waste. Except for a few isolated examples, C&D waste is not managed properly in India by ULBs. Common practices of waste management include (Figure 16):

- Reuse of valuable materials (by informal sector dealers)
- Illegal open dumping
- Use as filler materials in low-lying areas, especially before new construction
- Use in sub-base layer in roads
- Dumped in ULB designated dump yards (in a few cities only)

As discussed earlier, valuable materials salvaged from the waste, like whole bricks, door and window frames and metal are sold in the secondary market and reused in the construction of buildings. Similar to their role in MSW recycling, the informal sector also carries out a significant portion of the recycling activity of C&D waste. They collect commodities like wood and steel either for their own use or for selling them in the secondary market.

Table 7: Penalty for Illegal Dumping of C&D Waste

ULB	PENALTY FOR ILLEGAL DUMPING
Greater Mumbai Municipal Corporation	INR 20,000 (about USD 300) per truck
Navi Mumbai Municipal Corporation	INR 15,000-50,000 (about USD 225-750) per truck
Bhopal Municipal Corporation	INR 200-800 (about USD 3-12) per truck
Greater Bengaluru Municipal Corporation (BBMP)	INR 5,000 (about USD 75) per truck

Source: Authors' survey

The most common way of dealing with C&D waste is illegal dumping in open areas. Debris consisting of concrete, brick and mortar debris, and excavated earth is dumped illegally on roadsides, low-lying areas and river beds. This causes the waste to pile up on roads causing inconvenience, chokes surface drains, disrupts traffic and is an eyesore on the urban landscape. Some ULBs have introduced penalties on transporters to check illegal dumping, although enforcement can be highly variable (Table 7).

C&D waste is also used as filler materials in low-lying areas. In this case, the transporters are paid by the land owners. In some cities, C&D waste is mixed with municipal solid waste and dumped in ULB designated dump yards, where it is often used as cover for landfills.

Ahmedabad, Bengaluru, Chennai and Delhi have designated C&D waste dump yards. The Greater Bengaluru Municipal Corporation (BBMP) has published a circular with a list of eight (former stone) quarries around the city where the generators are supposed to dump C&D waste. Two of these quarries (Kannur and Mallasandra Village) are currently operational. Ahmedabad has 16 designated dump yards. Some ULBs levy charges for disposal in the dump yards. KMC charges generators INR 1,250 (about USD 20) per tonne per trip when transporting and dumping is done by KMC, and INR 550 (about USD 8) per tonne per trip for dumping when transportation is arranged privately by the generator.

Large scale processing of C&D waste has so far been implemented only in Ahmedabad and Delhi; other private small scale initiatives have also been observed in cities like Bengaluru. Different products like paver blocks, kerb stones, and aggregates for concrete and sand are produced. These products are used in the construction of buildings and other infrastructure.

Delhi has been a pioneer in the processing and recycling of C&D waste. In collaboration with the Municipal Corporation of Delhi, a pilot project was developed by IL&FS Environmental Infrastructure & Services Ltd (IEISL) in 2010. This public private partnership (PPP) has been initiated for 10 years to demonstrate the potential of a scientifically managed process for the collection and recycling of C&D waste in Delhi. In the processing facility, 2,000 tonnes per day of waste is collected from three designated zones of Delhi - Karolbagh, Sadar-Paharganj and City. The C&D waste is thereafter sorted and crushed to produce aggregates at the

Figure 17: C&D Waste Recycling Plant in Ahmedabad

waste management facility. These aggregates are then used to make Ready Mix Concrete (RMC), pavement blocks, kerbstones and concrete bricks. The products have been tested in various laboratories and found to be suitable for the designated purposes. This project demonstrates the viability of PPP models in processing of C&D waste (Figure 19). Building on the success of the first facility, another processing facility with a capacity of 500 tonnes per day has been commissioned at Shastri Park, New Delhi.

The Ahmedabad Municipal Corporation (AMC) has taken an important step by becoming the second ULB after Delhi to install and operate a C&D waste recycling unit with a processing capacity of 1,000 tonnes per day. This project is running on a PPP basis with Ahmedabad Enviro Projects Ltd. (AEP) since June 2014, where C&D waste is processed and recycled into aggregates. These aggregates are used to prepare finished products including paver blocks, kerbstones, concrete tiles, prefabricated structures, etc. The finished materials sold under the trademark Nu-Earth materials are used by the ULB contractors as well as independent local contractors. Currently, AEP is processing 300 tonnes per day of C&D waste on a pilot basis and is planning to increase the capacity in the near future.

Figure 18: C&D Waste Recycling Plant in Delhi

AMC has designated 16 spots in the city where citizens can bring the waste at their own cost. The waste generated by AMC civil works is also collected at these spots. Citizens can register their complaints for collection of construction debris by phone call on the AMC operated Comprehensive Complaint Redressal System (CCRS). Citizens are charged a minimum flat rate of INR 200 (about USD 3) per trip for the transportation of waste from the site to the disposal points. AEP collects the waste from these spots by their own vehicles. AMC pays the agency INR 155 (about USD 2) per tonne for collection and management. These two examples demonstrate that the success achieved by Delhi and AMC can be replicated in other cities of India.

Besides government initiated PPPs, the private sector has also taken an interest in the processing of C&D waste. Rock Crystals Pvt. Ltd., a stone crushing unit in Bengaluru, took the initiative to use demolition waste materials (mainly the cement concrete portion) as raw materials for construction material production. The demolition waste from major construction and demolition projects are brought to the operator by the generator and the waste is being processed into aggregates of 6 mm, 12 mm, 20 mm, 40 mm, GSB (mixed aggregates for roads) and M-sand. The operator processes an average of 2,500 tonnes per month of C&D waste. The material produced is of competitive quality and is in demand in the market especially during the monsoon (rainy) season when supply of virgin aggregates is often affected. The unit is also an empanelled member of BBMP for C&D waste management.

Looking at these models, more cities have expressed an interest in C&D waste management and processing. The Coimbatore Municipal Corporation has proposed a C&D waste recycling plant with a capacity of 200 tonnes per day. The proposal has been approved by the sanctioning authority and the commencement of work is proposed to start in 2015-16. The waste would be recycled into aggregates, sand and paver blocks. A business plan for profitable sale of paver blocks has been prepared by the Municipal Corporation. The Delhi Municipal Corporation is also in the process of establishing more processing facilities in other parts of the city with the long term goal of having one such unit in reasonable proximity to any given future project. Mumbai is in the process of preparing a C&D waste management plan for the urban agglomeration. Processing facilities will be set up after the finalisation of the plan. A Detailed Project Report (DPR) for the management of C&D waste is also being prepared by the Jaipur Municipal Corporation. Chandigarh and Vijayawada have also expressed interest in processing C&D waste.

3.2. Stakeholders Involved in C&D Waste Management

Construction is a disaggregated sector with complex inter-linkages among public and private stakeholders. Introducing paradigm shifts to transition towards resource efficient practices involves the coming together of all the stakeholders.

Table 8 illustrates the roles currently played by these stakeholders and a comparison with those specified in the Draft Municipal Solid Waste Management Rules 2015, which can be regarded as the ideal situation. The biggest gaps can be seen in the responsibilities of waste generators and ULBs. Submission of waste management plans and the management of waste at the demolition site by the generators is virtually non-existent today. On the other hand, lack of databases on C&D waste generated and collected by the ULB hinders the effective management of waste. Strict implementation of the new rules is essential for proper management and processing of waste in a city.

Figure 19: C&D Waste Processing in Delhi

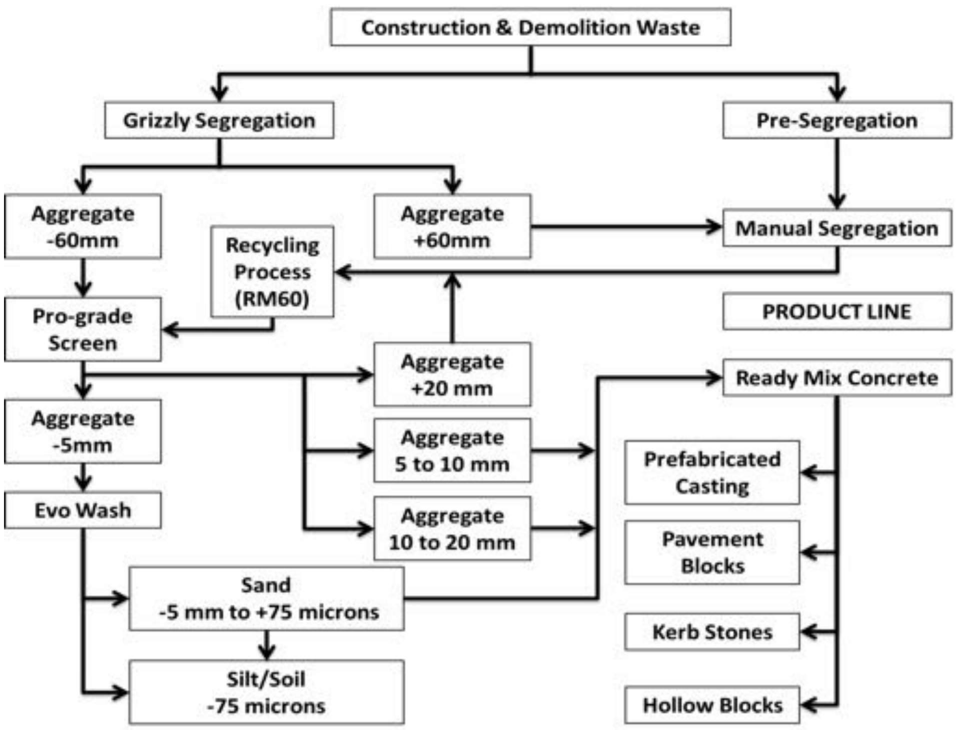


Table 8: Roles and Responsibilities of Stakeholders in C&D Waste Management

STAKEHOLDERS	CURRENT ROLES AND RESPONSIBILITIES	ROLES AS PER DRAFT SWM RULES, 2015
Waste Generators • Private developers • Government Departments involved in construction like PWD	• Demolish and construct new buildings • Apply for reconstruction permits to the ULB • Contact a contractor and issue tenders	• Apply for permits • Submission of undertaking of disposal of C&D waste and waste management plan to the ULB • Collection and storage of waste at site • Segregation of waste in four streams (concrete, soil, steel, wood and plastics and other wastes like bricks)
Demolition Contractor	• Demolition of buildings • Removal of C&D waste from site	---
Urban Local Body	• Regulatory authority (approvals for reconstruction) • Waste management of a city • Development of C&D waste management plan of a city • Setting up of C&D waste processing facilities with a private agency/contractor	• Issue detailed directions with regard to proper management of C&D waste • Seek undertaking and waste management plan from generators • Make arrangements for placement of appropriate containers or skips and their removal at regular intervals through own resources or by appointing private operators • Transportation of collected waste to sites for processing • Development of database of C&D waste • Information dissemination on waste management practices • Give incentives for use of recycled materials in construction
State Pollution Control Board	• No role played currently	• Monitor implementation of rules • Give authorisation for C&D waste processing facility • Monitor C&D waste processing facility for pollution compliance
Transporters • Public (empanelled) • Private	• Transportation of C&D waste to disposal sites (low-lying areas, open dumping or designated dump yards)	• Transportation of C&D waste to the designated disposal site
Contractors • Private firms like IL&FS, Ramky, etc.	• Integrated waste management (collection, transportation, disposal and management) in a PPP with the ULB • Processing of C&D waste	---
Informal Sector Waste Dealers	• Segregation at site and recycling of valuable materials	---

3.3. Cash Flow

Multiple cash flows exist in the C&D waste management process (Figure 20). Contractors who are primarily involved in the actual process of demolition are the key stakeholders. In most cases, contractors pay the waste generators for the purpose of demolition. The waste generator however does have to pay for the required approvals. The waste materials are segregated at site by the contractors and informal sector waste dealers. Valuable materials like metal and wood are sold by these demolition contractors in the secondary market. Contractors also pay a fixed amount to private transporters for the transportation of remaining debris to designated dump yards or other low-lying areas.

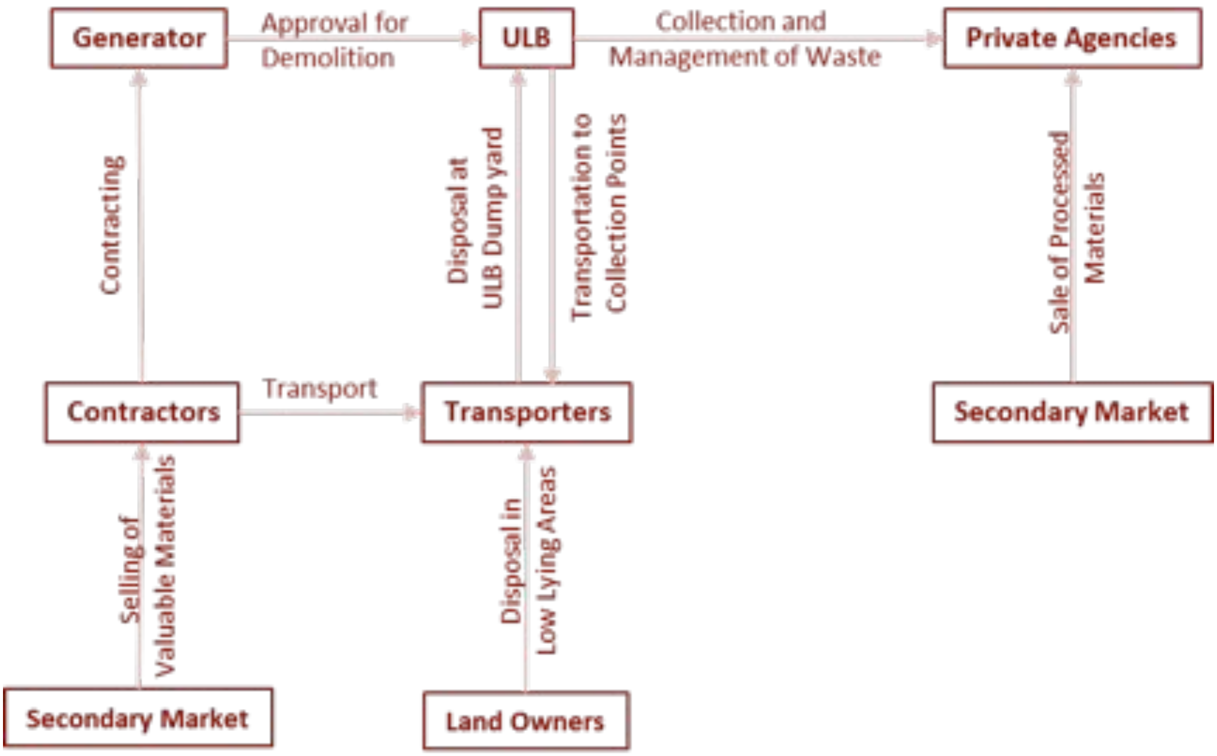


Figure 20: Cash Flow for C&D Waste Management

These transporters also charge land owners to dispose the waste in private low-lying areas when such land owners are planning to use this waste as a fill for future construction on that land. In this scenario, the waste is diverted from the designated dump yards to other locations. In a few cities like Kolkata and Chennai, transporters have to pay a fee for disposal for waste in ULB designated dump yards. In cities like Ahmedabad and Delhi, transporters are also empanelled with the ULB. These transporters collect waste from several collection points across the city to dispose it in the designated dump yards. The ULB pays a fixed fee to the transporters for this purpose. A few cities like Chennai have contracted private agencies like Ramky Enviro Engineers Ltd. for the management of the dump yards for a fee.

Delhi and Ahmedabad have been the first cities to set up C&D waste processing facilities in India. Due to limited technical and financial capacities of the ULBs and increasing emphasis on involvement of private sector from the Central Government, public-private partnerships were initiated. In such cases, the land for the processing facility was provided by the ULB. The private sector company set up the infrastructure for the facility. Building products produced by the facility are sold by these private companies in the market to generate revenue. This is a business model that is still evolving and needs to be fine-tuned to local context as necessary.

3.4. Challenges in C&D Waste Management

While the importance of C&D waste management is appreciated by stakeholders, especially in large cities where impacts are already being felt, implementation is far from ideal. Effective management of C&D waste is hampered by several challenges as enumerated below.

Regulatory Challenges

One of the biggest challenges is the lack of regulation on demolition. The existing regulatory framework for management of C&D waste and building bye-laws don't specify the need for demolition permits. They are only required in case of reconstruction or alterations in a building. In addition to site plans of buildings, no consolidated estimate of waste generated is recorded. Landfill records are also not maintained by the ULBs in most cases. As a result, C&D waste generated in a city cannot be estimated accurately. Attempts at estimation are also hampered by illegal dumping of waste in open areas and low-lying areas. The lack of effective regulatory framework and incentives to dump the waste in designated dump yards are some of the reasons for illegal dumping in the country. In fact, currently it is economically more viable to dump the waste illegally than to transport it to designated sites at a higher cost.

There is limited legislation controlling these processes and even limited capability at the ULB level to implement them. The lack of adequately skilled and driven manpower is another major challenge cities are facing.

Cities like Delhi and Ahmedabad process the C&D waste to produce building materials like paver blocks, aggregates and sand. However, the market for such products is limited due to the lack of codes and standards for these materials and their use in construction.

Market Challenges

As mentioned earlier, time and cost factors determine the methods of demolition in a city. In the southern parts of India, buildings are demolished by mechanised means, reducing the amount of building materials that can be reused. Lack of profitability due to time constraints, high labour costs and poor quality of some building materials (e.g., bricks) forces the contractors to demolish buildings wholesale and dump the mixed debris. This prevents segregation and reuse of materials.

Dumping of C&D waste in low-lying areas is a common practice in the country. It is often a method of earning more revenue by the transporters. They sell the C&D waste to the owners/builders of plots having low-lying areas rather than paying to dump in the designated landfill. Landowners and builders typically pay for such debris since they use it as fill material before new construction can take place.

While C&D waste processing has been introduced in some cities, the market demand of the materials produced is unreliable due to the low levels of awareness of users about such products and concern about inferior quality. Users also don't see any incentives for the use of these products as compared to conventional materials.

Technological Challenges

Effective C&D waste processing systems have been successfully operational in many countries. However, limited information on the available processing technologies and limited technology service providers deter ULBs from setting up processing facilities in their cities. Also, in India, these units are seen as viable only in a PPP setting so far, a mode of working many ULBs are still unfamiliar with. The lack of technical understanding and capability of ULB officials is another constraint.

Demolition of buildings quickly and cheaply and disposal of the resulting debris prevents recovery and reuse of suitable materials. Deconstruction is a suitable alternative that maximises the recovery of materials from a building. It is a process of carefully dismantling a building in order to salvage maximum number of components for reuse and recycling. This process is popular in several countries like the USA, Belgium, Germany, Spain, etc. However, it is not followed in India due to lack of awareness on the process. The designs of the buildings are also often not conducive for deconstruction. Lack of available technologies adds to the poor uptake of this concept.

Resource Challenges

Land for disposal of waste is increasingly becoming sparse. Most ULBs cannot afford to designate more land as landfills or dump yards. Currently, Kolkata has one dump yard (Dhapa) which is encroaching a Ramsar[12] wetland site, threatening to pollute it (Times of India, 2013). As a result, the KMC is in the process of identifying other sites. However, the ULB has cited land constraints as a major hurdle. The C&D waste of Mumbai is being dumped in adjoining areas like Navi Mumbai, Thane, etc., due to lack of land in the city proper. This concern emphasises the urgency of looking at alternatives.

3.5. Good Practices in C&D Waste Management

Pilot initiatives in Delhi, Ahmedabad and Bengaluru have shown that C&D waste can be recycled and reused in construction. While such efforts are commendable, good practices across the world offer lessons for developing, implementing and sustaining an effective C&D waste management system. Several initiatives from across the world show the way to counteract the challenges faced by India in the management of C&D waste.

Regulation

Several countries have developed legislative frameworks and policies for waste management. The Waste Framework Directive 2008/98/EC of the European Union set quantitative targets for reuse of C&D waste. It states "*by 2020, the preparing for reuse, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 percent by weight*" (European Commission (DG ENV), 2011).

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[12] Protected wetland according to Ramsar Convention of 1971

Flanders, Belgium introduced use of secondary raw materials in the Flemish legal framework from 1997 onwards. They also developed a plan specifically for C&D waste in 1995. This plan for C&D waste introduced quantitative targets for the period 1995-2000. It aimed at recovering 75% of all C&D waste generated by 2000 and prevent its generation by 25% in the medium term. 85% of the waste had to be sorted into recyclable waste, recycling residue and hazardous waste by 2000. These wastes were also to be treated to allow recovery or recycling, thereby generating less recycling residue. Apart from these quantitative targets, it also aimed at generating market demand for products developed from recycled waste. The current target for recycling of C&D waste has increased to 90% (Eionet, 2015). The Flemish Government is also planning to impose material use prescriptions by developing environmental profile of construction materials (European Commission (DG ENV), 2011).

Germany's Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal, 1994, set principles for development of waste management in order to transition to a closed loop economy. It emphasises prevention of waste generation rather than recycling of waste. However, recycling is more preferable to the disposal of waste, and waste should only be disposed when recycling is not possible or is too expensive (European Commission (DG ENV), 2011). The Federal Cabinet of Germany adopted the German Resource Efficiency Programme (ProgRess) in 2012. ProgRess also promotes recycling of C&D waste (Federal Ministry for the Environment, 2012).

The Second National Plan of C&D Waste 2008-2015 of Spain sets out the objectives of prevention, re-use, recycling, other forms of recovery, and disposal, as well as outlines the means to achieve these objectives, including the financing system. Apart from setting quantitative targets for recycling of waste, it also sets qualitative targets. Among the qualitative targets are: the reduction of waste at the source, the correct management of all hazardous waste and the closure of landfills (European Commission (DG ENV), 2011).

Ireland's National Waste Policy aimed to achieve at least 85% recycling of C&D waste by 2013. They also published Best Practice Guidelines on the Preparation of Waste Management Plans for Construction and Demolition Waste Projects in 2006. Site Waste Management Plans (SWMP) in England, Wales, Scotland and Ireland ensure that building materials are managed efficiently and waste is disposed of legally, and material recycling, reuse and recovery is maximised (Lamb, 2011).

In 2000, Japan introduced the Construction Waste Recycling Law. It specifies the responsibility of contractors in sorting and recycling the demolition waste when the total floor area of the building demolished is greater than 80 m^2. Demolition contractors are required to separate and recycle specific construction wastes such as concrete including precast plates, asphalt, and wood building materials (Ministry of the Environment, 2000).

Increasing landfill costs has emerged as a driver for increased recycling and processing of C&D waste. Many European countries as well as Australia charge high fees for disposal of waste in landfills, while Finland and Hong Kong also incentivise waste generators to reuse and recycle the waste (Edge Environment Pvt. Ltd., 2011). In fact, Flanders (Belgium) and Netherlands have prohibited landfilling of C&D waste (European Commission (DG ENV), 2011).

Countries also give due importance on estimation of C&D waste. The holder of an urban planning licence in Flanders (Belgium) will have an architect or an expert appointed by the principal write up a waste materials demolition inventory when demolishing or dismantling commercial or industrial buildings with a construction volume in excess of 1,000 m^3. Spain, Hungary and Abu Dhabi also emphasise on keeping records of C&D waste handled (Edge Environment Pvt. Ltd., 2011).

Codes and standards for use of recycled materials also play an important role in promoting the use of materials produced from C&D waste. South Korea has separate building codes for recycled asphalt concrete aggregates, recycled concrete aggregates, and road pavements (CSE, 2013). Germany and Spain have developed guidelines for use of recycled aggregates. As per the European Committee for Standardisation (CEN) Aggregate Quality Standards, Finland has set technical quality requirements for use of C&D waste in production of aggregates. In Flanders (Belgium), the implementation order of the waste framework policy (VLAREA) assesses the conditions of use of secondary raw material in construction. These requirements are mandatory. Other voluntary standards on construction products and particularly secondary raw materials, such as COPRO or QUAREA, request use of secondary raw materials. In Finland, the Government Decree on the Recovery of Certain Wastes in Earth Construction (591/2006) promotes recycling of waste in some constructions activities such as public roads, parking areas, sports grounds, etc. (Edge Environment Pvt. Ltd., 2011).

Technology and Management

Deconstruction is popular in several countries like USA, Germany, Spain, Belgium, Hungary, etc. Controlled deconstruction is one of the most commonly used waste management practices in Germany. Windows, doors, heating systems, etc. are taken out of the building and can sometimes be reused as such, thus reusing a high percentage of materials. After deconstruction, building materials are sorted by material (bricks, concrete, wood, etc.) on site. This practice has replaced the traditional wrecking ball in Germany, Austria, Switzerland and parts of northern Italy. Before controlled demolition is carried out, a detailed planning including a concept for controlled demolition and disposal or recovery has to be performed. Detailed planning for deconstruction has also been introduced in Spain (European Commission (DG ENV), 2011).

Initiatives are being taken by building administrators or Resident Welfare Associations (RWA) in townships in India to collect and dispose C&D waste. RWAs in condominiums in Gurgaon have issued notices to home owners to not mix C&D waste with MSW. The waste is collected in separate bins and transported to designated dumpsites by contractors. Such initiatives show the increasing levels of awareness on C&D waste in India.

Market Mechanisms

Green ratings for buildings and infrastructure utilising materials from C&D waste in Australia, Germany and United Kingdom have been instrumental in popularising the use of recycled materials. The Green Building Council of Australia (GBCA) has developed Green Star tools for rating buildings on sustainability. Leadership in Energy & Environmental Design (LEED) is the US based green rating system developed by the United States Green Building Council (USGBC) which gives green ratings to buildings. C&D waste reduction and management is one of the criteria for these ratings. The green rating tool for infrastructure by the Australian Green Infrastructure Rating Council specifies the use of low embodied materials in construction (Edge Environment Pvt. Ltd., 2011). The German Sustainable Building Certificate, a voluntary scheme run by the German Sustainable Building Council (DGNB26) sets criteria to ensure the sustainability of buildings. These criteria also include C&D waste:

- Ease of dismantling and recycling.
- Construction site/construction process, establishing that the waste produced on-site should be prevented or recycled, and, if not recyclable, disposed of in a way that prevents harm to the environment.

The construction industry in Germany took the initiative to reduce the amount of landfilled C&D waste by 50%. It monitors its progress against voluntary commitments and issues bi-annual reports to the authorities, showing levels of accomplishment above EU targets (European Commission (DG ENV), 2011).

These best practices should be studied in greater detail to identify possible lessons for the Indian context.

Chapter 4: Moving Forward

Adoption of resource efficiency measures highlights the link between conserving resources while simultaneously reducing costs and thus strengthening the competitiveness of industries, as well as contributing to meeting India's future demand of resources. As the largest consumer of resources in the country today, the construction sector needs to look seriously at issues of resource efficiency.

Use of secondary raw materials like C&D waste presents a win-win approach for resource efficiency. Utilising a waste or by-product eliminates the problem of waste management, especially for bulky waste that needs a lot of expensive land to store in non-productive ways. Simultaneously, by reducing pressure on virgin resources, it aids in reducing environmental degradation and pollution. The Draft Solid Waste Management Rules (2015) puts emphasis on the efficient management of C&D waste. Use of the waste as a raw material for the construction sector will also help the ULBs in complying with the new rules. With the expected finalisation of the said rules in the near future, all ULBs will soon have to be ready to start implementing C&D waste management systems in their respective jurisdictions.

Pilots in Delhi and Ahmedabad have led the way in proving feasibility. Metals, wood and other materials like ceramics contribute to 10% of the total C&D waste generated in India. These materials already have a high recycling rate. They are segregated and sold in the secondary market by both the formal and informal sectors. The remaining waste consists of bulky materials. Of this, about 85% can be used productively in the construction sector. The products produced by processing the waste are likely to be restricted to non-structural applications in the near future in India. Still, they would alleviate the pressure on resources used in the production of ancillary products like paver blocks and kerbstones. Nevertheless, a lot needs to be done before such approaches are mainstreamed in both construction and waste management.

In order to promote resource efficiency in the construction sector through the use of secondary raw materials, policy and market decision makers should be informed about various available options and models on resource efficiency to create a better ecosystem. The following measures are important for promoting C&D waste management and utilisation in the Indian context.

Fine-tune Estimation Methodology for the Indian Context

One of the first things that needs to be addressed is to assess and estimate the quantum of C&D waste generated. While the present study throws some light on the magnitude of the issue, a more **detailed quantification and characterisation study** is required to better plan the most appropriate waste management strategy.

Build Capacities of ULBs

The role of managing waste including C&D waste rests with the ULBs. Thus it is important that the ULB officials have the technical and managerial capacity to do so. This is currently a gap due to the lack of easy access to tools, methodologies and technologies that can aid this process. Thus, one aspect of future work can be the development of an easy-to-use guide for ULBs to estimate and plan for the C&D waste generated. **Good practice guidelines and manuals for the entire waste management cycle** ranging from estimation, collection, segregation, processing and final disposal of C&D waste should be developed and shared with the ULBs.

Provide Technical Support to New Entrepreneurs

Another hurdle faced in the effective use of secondary material streams like C&D waste is the availability and accessibility of suitable technologies. There is often a knowledge gap in knowing where to go to seek such solutions, i.e., a lack of technology and service providers. Furthermore, if such technology is imported, as is often the case, there may not be adequate in-house capacity to **operate, manage and troubleshoot** them. This lack of technical support often deters entrepreneurs from engaging in waste management ventures. Technical support to new entrepreneurs from the current processing units will encourage more entrepreneurs to engage in the processing of C&D waste.

Box 1: Model for Micro Enterprise for C&D waste processing
<u>Enterprise details</u> • Micro enterprise: ~ INR 2.5 million investment • Product: Paving block (can be expanded to other building materials with low CAPEX) • Working days: 300 in a year • Production capacity: 2,000 blocks per day • Paving block: ~ 5 kg weight (hexagonal) • Composition: 1:2:4 • Raw materials: cement, stone dust, C&D waste aggregate • Annual consumption: 2,000 tonnes per enterprise <u>Impacts</u> • Jobs created: 6-8 persons • Waste utilized: 2,000 tonnes per year • Business generated: INR 9 million/year (INR 15 per block)

Source: Based on authors' survey and calculations
(USD 1 = approx. INR 65)

Build a Business Case for Private Entrepreneurs

Weak business models due to uncertainty in the supply of raw material and limited market penetration of the processed product (due to lack of awareness and perception of inferior quality) are other barriers entrepreneurs face. Test results from this study (see Annex 3) show that paving blocks made with C&D waste from Ahmedabad and Bengaluru fulfil the properties of compressive strength as per BIS code 15658:2006.

Therefore, paving blocks for non- traffic, light-traffic and even medium-traffic can be produced safely with C&D waste. In addition to meeting technical requirements, such products also offer cost reductions ranging from 19 – 33% depending on the availability of C&D waste (see Annex 3). Thus it can be **an economically viable business for small entrepreneurs**. However, potential entrepreneurs should be made aware of the technical and economic viability of such enterprises through demonstrations and publications.

Figure 21: The Technology Package

Create Large Scale Awareness and Sensitise Users

The lack of familiarity with the products and hence inadequate confidence on the quality drives away potential users. The general perception associating a waste based product with substandard quality, especially when compared to those using virgin resources, needs to be broken through **large scale awareness** and sensitisation. Targeted awareness campaigns should be developed for industry associations for architects, construction and real estate.

Develop Favourable Policies for Products Made Using Secondary Raw Materials

Codes and standards that ensure products meet quality standards will go a long way in building user confidence in products made from C&D waste. BIS is already in the process of revising the standard for aggregates to accommodate recycled aggregates, but this is a new development that is not well known and needs to be publicised. Besides, more such standards are necessary for other kinds of products and applications. Further, incentivising the market, as has been done for fly ash based bricks, through preferential policy treatment will help overcome initial market barriers.

Even at current waste generation levels, there is scope for multiple enterprises to come up in each city. The number ranges from 400 in Delhi to 10 in Coimbatore[13], thus demonstrating the significant employment potential. However, in order to safeguard the interests of these small and medium enterprises, it is essential to create a favourable policy environment wherein technology, economic and capacity concerns are dealt with. Advocating lessons from demonstrations and studies on the ground with decision makers in the public and private sectors will encourage them to explore, understand, assess and promote good practices such that they move from pilot examples to the norm.

[13] Based on C&D waste generation estimates in each city and proposed capacity of micro enterprise depicted in Box 1.

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ANNEXURES

Annex 1: Survey Design

It is important to estimate the quantity of secondary raw materials available as well as understand their quality in order to achieve reuse. Since there is no standard procedure for quantification and characterisation of C&D waste in India, a proper practical methodology has to be derived for the study.

Objective

This study focuses on construction and demolition (C&D) waste to explore its potential as a secondary raw material in the construction sector. Thus the key objectives of this study are:

- To quantify and characterise the construction and demolition waste generated in select cities in India
- To understand current practices and potential use of C&D waste in construction sector
- To shortlist cities for conducting pilots

Approach

As a first step, a proper methodology is to be derived for the quantification and characterisation study which is fine tuned to the Indian context. The study will use a iterative process involving secondary literature and primary research which will be analysed and extrapolated for the nation.

Detailed Methodology

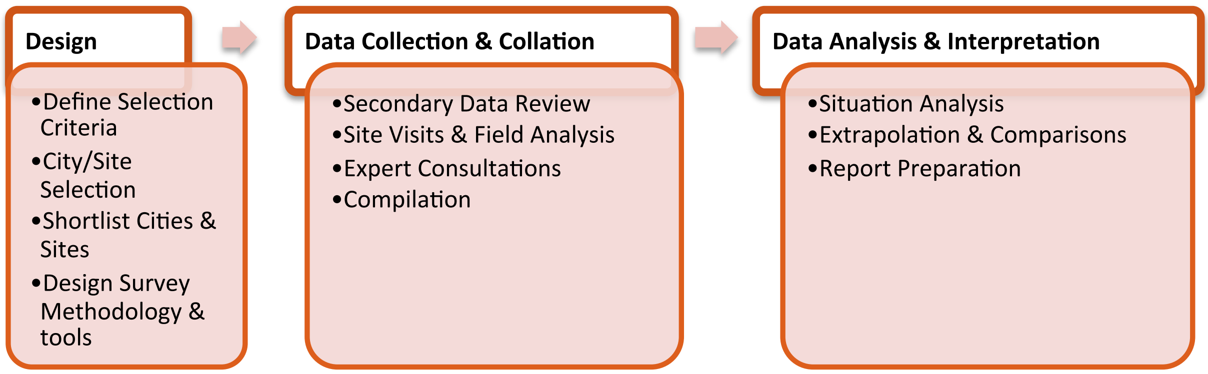
The methodology is divided into three basic stages: Design, Data Collection & Collation, and Data Analysis & Interpretation.

Design Stage

This stage will lay the basis for the rest of the study.

- One of the first steps will be to define the selection criteria for the study cities. Urban areas, being the most intensive source of C&D waste generation, are prioritised for the study. A handful of criteria (described below) will then be applied to various cities in the country to derive a shortlist of cities that will be studied. Further, 5 sites will be selected in each of the cities for sample and data collection, i.e. demolition sites.
- The other important part of this phase is the design of survey methodologies and tools. Semi-structured questionnaires will be developed for various stakeholders to understand their attitude and practice with respect to C&D waste. A list of stakeholders will be developed to conduct the study. They include:

- ULB officials, Line departments
- Collection contractors including informal sector
- Recyclers / Waste managers
- Developers as waste generators as well as users
- Technical experts like architects, engineers, etc.
- Building material manufacturers
- Research institutes



Schematic Methodology

Data Collection & Collation

This phase forms the heart of the study, where all the data and information will be collected.

- Secondary literature and data review will help inform the site / city selection process and build an understanding on the current prevailing practice in the city.
- Site visits will be used to develop a first hand understanding on the C&D waste situation in the city. The survey will explore the following aspects and their impact on the quantity and character of the waste generated.
    - Location, typology, and construction style / components
    - Management status of critical materials
    - Recyclability potential
    - Time of the year
    - Age of building
    - Market demand / cost
    - Presence of hazardous materials
- The information collected / observed will be corroborated by views of experts from the private and public sector involved in this area.
- All data collected will be compiled for detailed analysis and interpretation.

Data Analysis & **Interpretation**

This is the most important stage of the study as it presents the results and sets the tone for the rest of the project.

- The collated / compiled data will be analysed based on a framework developed to understand the impact of aspects of typology, time, construction practice, market demands, etc. on the generation and composition of C&D waste.
- Based on the understanding developed through primary research on the selected sites, an extrapolation exercise will be undertaken to stretch these assumptions and results to help outline a national scenario. This will be compared across various scenarios as well as the situation in other countries particularly Germany.
- A report will capture this entire process and the findings, thus creating a view on the C&D waste estimation and characterisation in the country.

Important Points

- Pilot identification will also be undertaken in the course of this study.
- Extensive baseline data will be collected for the selected pilot intervention sites.

City Selection Criteria

The cities were selected based on selected parameters as mentioned below

- **Population / City Size:** Cities will be selected under two heads based on population and size. Since the nature and pattern of growth of metropolitan / mega / 5 million plus cities is very different from that of other Tier 1 cities, both these classes will be consider separately. Tier 1 cities represent the rapidly urbanising community of waste generators and potential consumers.
- **Urbanisation:** Cities which urbanise rapidly require more living space, working space and infrastructure, leading to more and more construction projects in the city. Hence rapidly urbanising cities have a greater potential for C&D waste generation. The cities with high urbanisation rates in past few decades would be most preferred for the study.
- **Geographic Spread:** Cities to be sampled would be selected from across the country. India is conventionally divided into 5 zones - North, South, East, West and Central. A representative sample will be picked from each zone.
- **Investment Zones:** The interest of different stakeholders in investing in the construction sector in the regions holds a key to the future trends for construction activities in a city. Hence cities in regions and zones where there is chance for immediate investment for infrastructure / industrial development will be prioritised.
- **Expression of Interest from Stakeholders:** Stakeholder interest, especially from the government, is a major consideration, as implementation of any development activity depends

on the interest expressed and acted upon. Any stakeholder who has expressed prior interest or who gives positive response to primary studies will be given preference.

Based on the preliminary selection criteria, ranking of all major cities were performed and 10 cities were shortlisted from the group.

CATEGORY	CITY	WASTE GENERATION (POPULATION) (OUT OF 5)	INVESTMENT ZONES (OUT OF 5)	STAKEHOLDER INTEREST (OUT OF 5)	RATING
Metro City	Mumbai Urban Agglomeration	5	5	4	14
	Delhi Urban Agglomeration	5	5	5	15
	Bengaluru Urban Agglomeration	3	3	5	11
	Hyderabad Urban Agglomeration	3	3	2	7
	Chennai Urban Agglomeration	4	5	2	11
	Calcutta Urban Agglomeration	5	5	1	11
Tier 1 - North	Agra	2	1	1	4
	Jaipur	3	1	1	5
	Chandigarh	1	1	1	3
Tier 1 - East	Bhuvaneshwar	1	1	1	3
	Patna	2	1	1	4
Tier 1 - West	Surat	1	1	1	3
	Ahmedabad	2	1	3	5
	Pune	3	1	1	4
Tier 1 - Central	Jabalpur	1	1	1	3
	Bhopal	2	1	1	4
	Indore	1	1	1	3
Tier 1 - South	Visakhapatnam	3	2	1	5
	Coimbatore	4	1	2	7
	Mangalore	1	1	1	3
	Cochin	3	1	1	5
	Trivandrum	2	1	1	4

Based on the selection criteria, the five most high ranking Metro cities and Tier 1 cities were selected. Points were assigned through secondary data search and consultative exercise with stake holders conducted for each city mentioned above.

Mega Cities: Mumbai, Delhi, Kolkata, Chennai, Bengaluru

Tier 1 Cities: East: Patna; West: Ahmedabad; North: Jaipur; South: Coimbatore; Central: Bhopal, Jabalpur

Stakeholder List

The key stakeholders in the process of waste generation and management have been identified at the local level. These include:

- **ULB Officials:** Urban Local Body officials are in charge of the overall waste management in the city, including C&D waste.
- **Contractors:** Contractors are involved with direct waste handling and sometimes also disposal / management; can include the informal sector.
- **Developers:** Developers are one of the major waste generators, producing the bulk of C&D waste; also potential users of products derived from C&D waste; includes large organisations / PSUs.
- **Recyclers / Waste Managers:** They are in charge of waste management and final disposal. They might even be involved in the collection chain. Governed by market forces.
- **Technical Experts:** Technical experts like architects, engineers, etc., as users of products derived from C&D waste; future market for resource efficiency interventions.
- **Building Material Manufacturers:** Building material manufacturers are users of the C&D waste to create products / secondary raw material use.
- **Building Material retailers/suppliers:** Useful to question this group to understand the demand-supply gap of materials, potential for C&D waste based product market, current price of materials, distance from where this virgin material is coming to their city, etc.
- **Research Institutions:** Research institutions like IITs, CBRI, CRRI, IISc, CII – IGBC, etc. on productive use of C&D waste into products, technologies for the same.

Sample Questionnaire

Urban Local Bodies & Contractors / Waste Managers

1. What is the quantum of C&D waste that is collected per day inside governance area (tonnes/day)? What is quantum of construction and demolition in the region (m^2 per year)? Does the quantity of waste depend on seasonal variations? If Yes, then please elaborate.
2. How/When is the C&D waste collected? What all materials are collected from site? (or) what materials are not collected? How is it decided what to collect and where to collect? Process Flow?
3. Is the C&D waste collected in a segregated manner or is it mixed with MSW? Is the C&D waste collected from source (owner's property) or a collection point? If collection points, then how many collection points are there? What happens to the component of waste which is not collected?
4. Have the C&D waste been characterised? If Yes, what is the detailed breakup of components in percentage? If not, rough estimations of composition – element wise?

5. What is the C&D waste management policy? Is there any program or scheme to support C&D waste management?
    a. Is there a C&D landfill in operation? Is there plan for a new C&D landfill or new units to existing landfill? If Yes, then details?
    b. Is the C&D waste processed or recycled? if Yes, what is the process? Is the recycled/reused products marketed? If Yes, details?
    c. Are valuables from C&D waste collected by rag pickers during the process of collection and transportation? If Yes, which components?
6. Who performs collection and transfer of C&D waste, is a private entity involved? If it is a private (contractor / consultant), who is/are the private entity? For how long has the private contractor been involved and how long is the contract?
7. Who operates the processing facility?
    a. If it is a private (contractor / consultant), who is/are the private entity? For how long has the private contractor been involved and how long is the contract?
    b. If there is a processing facility then was it built on any special fund?
8. How and where is the C&D waste disposed? What is the technology used? Who operates and maintains the disposal facility? If it is a private (contractor / consultant), who is/are the private entity? For how long has the private contractor been involved and how long is the contract? What is the payment and operational terms with the private entity?
9. Is there illegal dumping of C&D waste? Is there a penalty or punishment for illegal dumping of C&D waste? Illegally dumped C&D waste if found, is it collected?
10. What are the constraints faced with C&D waste? Do you wish for a change in the present C&D waste management practices? If Yes, please brief a few points?
11. Are you interested in implementing better C&D reuse and management programs?
    a. Are enough IEC activities being performed among the public to avoid open dumping of C&D waste and for proper disposal of waste with the ULB?
    b. Is there any fund or scheme from the state government in the new budget which could be utilised for development of C&D waste management services?
    c. Is there any support provided by banks or is it available on request? If Yes, then details?
12. Which construction materials have resource shortage in the region?

Developers

1. What is the demolition technique used?
2. Is the C&D waste load quantified before clearance?
3. Is the demolition process outsourced or are in-house resources used? If outsourced, then what is process of outsourcing?
4. Have the C&D waste been characterised? If Yes, what is the detailed breakup according to the type of building? If Not, what is the rough estimate and which are the main components?

5. What is the C&D waste management practice on the site (what is done with it)? What do you do with your C&D waste? What do you do with your renovation waste? What is the common C&D waste management technique used by other developers?
    a. Do you engage professionals or contractors for demolition / construction / renovation purposes?
    b. Is any part of C&D waste reused on site itself? If Yes, then how and what percentage? Is the reusing of C&D waste profitable? If Yes, what is the percentage? Do reused/recycled materials affect quality of construction? If Yes, then how?
    c. If the municipal authorities / contractors collect the waste, is it done on time? What are the payment terms for waste collection (what, how, who and where)?
6. Do you wish for a change in the present C&D waste management practices? If Yes, please brief a few points?
7. What is the growth potential of the city (with reference to land availability, resources and activities) in terms of construction?
8. Which construction materials have resource shortage in the region? What is the cost of major raw materials used for construction? (sand, soil, aggregates, bricks, steel, concrete)
9. Do you wish to use building materials made out of C&D waste which are much less costlier, for construction or renovation purposes?

Technical Experts / Material Manufacturers

1. What is the growth potential of the city (with reference to land availability, resources and activities) in terms of construction?
2. What are the commonly used reuse or recycle technologies used in the region?
3. Is there an applicable reuse / recycle technique or technology that could be used which is currently not being practiced? If Yes, is it being practiced somewhere and the reference?
4. Is there any innovative technology being used for raw material resource efficiency in the region which could be given more attention? If Yes, then the reference?

Annex 2: Sampling Sites

CITY	SAMPLE	SITE SPECIFICATION
Mumbai	MU1	G+3, demolition site, 45 year old building
	MU2	G+3, demolition site, 60 year old building
	MU3	G+2, demolition site, 25 year old building
	MU4	G+5, demolition site, 30 year old building
Chennai	MA1	G+1, demolition site, 25 year old building
	MA2	G+1, demolition site, 25 year old building
	MA3	G+2, demolition site, 40 year old building
	MA4	G+1, demolition site, 25 year old building
	MA5	G+1, demolition site, 50 year old building
Kolkata	KO1	G+1, demolition site, 30 year old building
	KO2	G+2, demolition site, 40 year old building
Bengaluru	BA1	Dumping yard
	BA2	G+2, demolition site, 25 year old building
Ahmedabad	AH1	G+2, renovation site, 20 year old building
	AH2	G+1, demolition site, 30 year old building
	AH3	G+2, demolition site
	AH4	Dumping yard
Jaipur	JA1	G+1, demolition site, 50 year old building
	JA2	G+1, renovation site, 15 year old building
	JA3	G+2, demolition site, 30 year old building
	JA4	G+2, demolition site, 40 year old building
Bhopal	BH1	G+1, demolition site, 60 year old building
	BH2	G+0, demolition site, 60 year old building
	BH3	G+2, demolition site, 50 year old building
	BH4	G+3, demolition site, 50 year old building
Coimbatore	CO1	G+1, demolition site, 25 year old building
	CO2	G+2, demolition site, 50 year old building
	CO3	G+3, demolition site, 50 year old building
	CO4	G+16, demolition site (top 2 floors), 5 year old building
	CO5	G+1, demolition site, 60 year old building
Delhi	DA1	G+2, renovation, 30 year old building
	DA2	G+1, renovation, 35 year old building
	DA3	G+1, demolition site, 50 year old building
	DA4	G+2, renovation, 15 year old building
	DA5	G+1, demolition site, 50 year old building
Patna	PA1	G, demolition site, 50 year old building
	PA2	G, demolition site, 50-60 year old building
	PA3	G, demolition site, 50-60 year old building
	PA4	G+1, demolition site, 50 year old building

Annex 3: Comparison of Paving Blocks Made of Natural Aggregates and C&D Waste

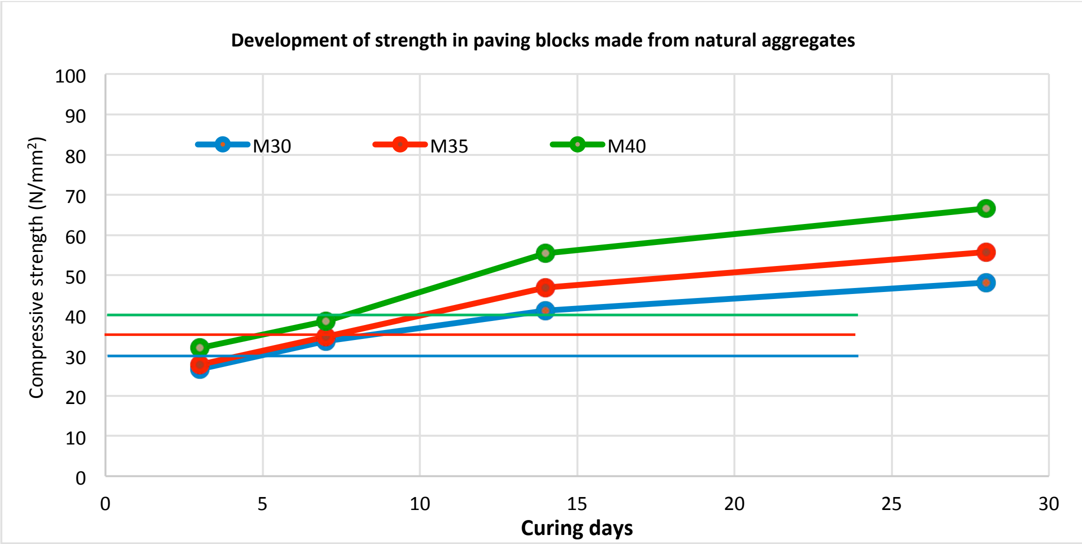
A comparison in the strength of paving blocks manufactured from C&D waste and natural aggregates was done for two cities (Ahmedabad and Bengaluru). Normally, paving blocks are made in the ratio of 1:2:4 (cement : sand : stone aggregates). In the present experimentation, keeping the recipe same, the stone aggregates have been entirely substituted by crushed concrete from C&D waste. The concrete was segregated from collected C&D waste and crushed in a jaw crusher to the required size of 12 mm and 20 mm. The finer sizes were rejected by sieving. The reject percentage was less than 3%, thereby not affecting the yield of usable material. 12 mm and 20 mm concrete aggregates from C&D waste was used to make paving blocks of 60 mm and 80 mm thickness respectively.

3 grades of paving blocks were made: M30, M35 and M40, based on a mixed design. M30 grade paving block can be used in non-traffic areas used in building premises, monument premises, landscapes, public gardens/parks, domestic drives, paths and patios, embankment slopes, sand stabilisation, etc. M35 grade can be used in light traffic areas designated for use in pedestrian plazas, shopping complexes, ramps, car parks, office driveways, housing colonies, office complexes, rural roads with low volume traffic, farm houses, beach sites, tourist resorts, local authority footways, residential roads, etc. M40 grade paving block can be used in medium traffic areas for use in city streets, small and medium market roads, low volume roads, utility cuts on arterial roads, etc.

Cement used was of OPC 43 grade. The water to cement ratio for M30 and M35 grade paving block was kept at 0.45 and for M40 it was 0.42. All the blocks were vibrocasted in a vibrating table. The freshly casted blocks were atmosphere cured for 24 hours and stacked in layers. They were cured for 14 days by water sprinkling. After 14 days they were left to cure under normal atmosphere. Development of strength was tested at 7 days, 14 days and 28 days. Testing was done as per IS 15658:2006 (specifications for precast concrete blocks for paving). Parameter that was not tested was water absorption.

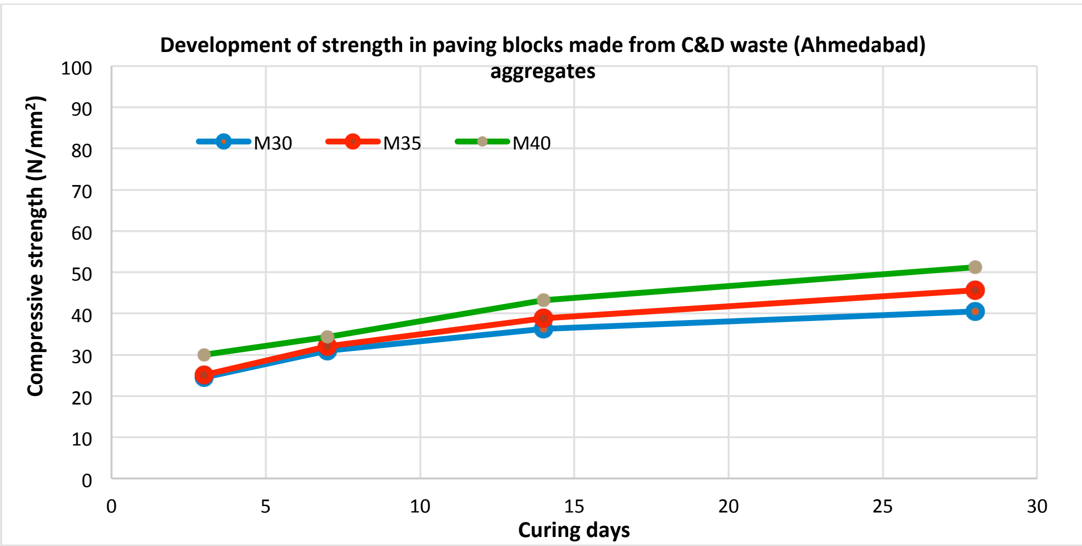
The samples collected were processed and paving blocks produced from the same. These were tested to give the following results. They were compared with products made from natural aggregate.

Strength testing in product made from natural aggregates:

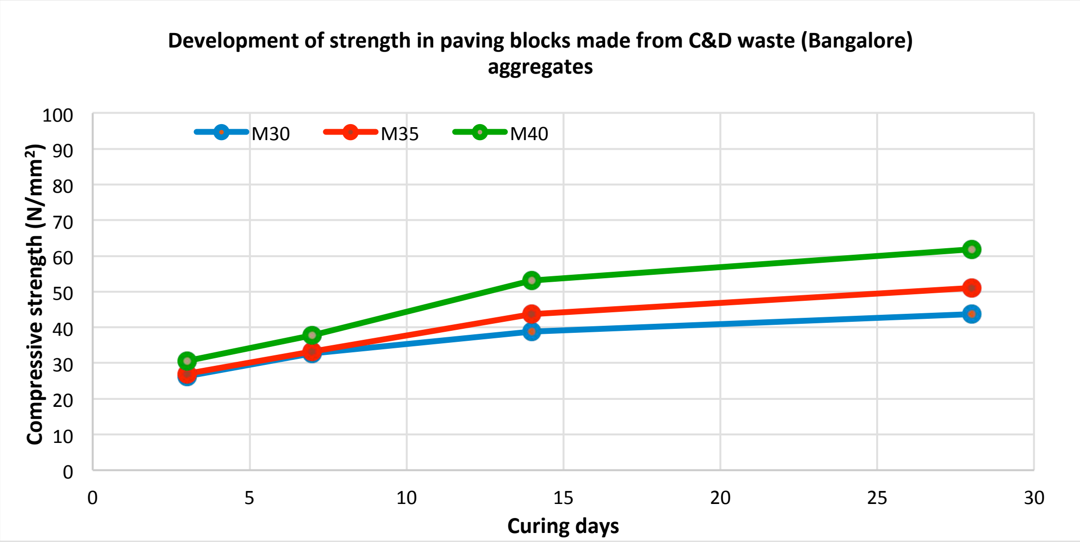


It was observed that 100% strength was achieved within 7 days. The rate of strength increase was similar in all grades of paving block. However, an average of 60% higher strength was seen in all grades for natural aggregate based paving block.

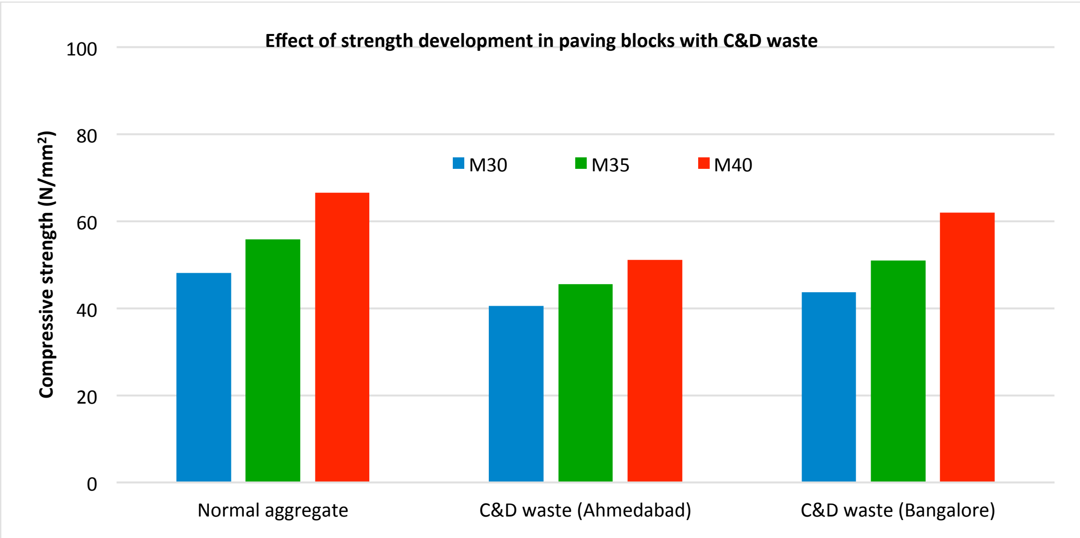
Strength testing in product made from C&D waste aggregates:



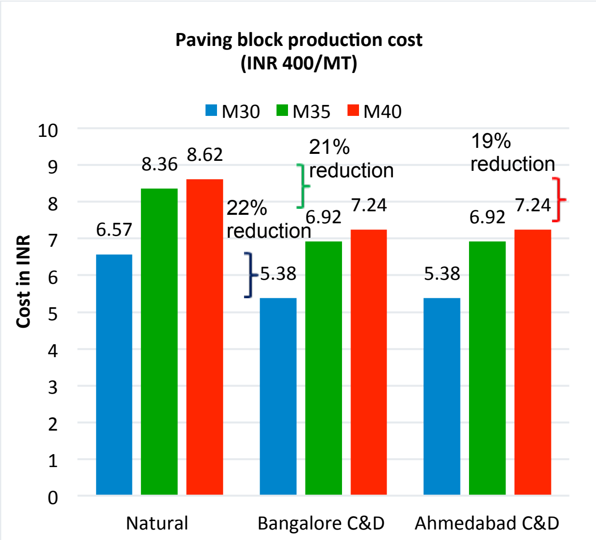
M30 grade paving block achieved 100% strength within 7 days while in M35 and M40 grade strength was achieved within 14 days. The rate of strength increase is similar in M30 and M35 grades of paving block but M40 grade paving block has an improved strength development. On an average 30% higher strength seen in all grades for paving block using Ahmedabad C&D waste (compared to standard for paving blocks made with natural aggregates).

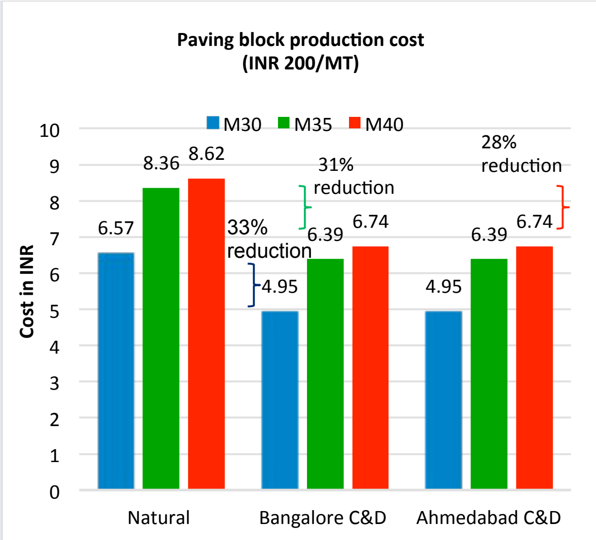


All grades of paving block achieved designated strength within 7 days. The rate of strength increase was similar in M30 and M35 grades of paving block. M40 paving block has a distinct strength build up pattern. An average of 45% higher strength was seen in all grades for paving block using Bengaluru C&D waste (compared to standard for paving blocks made with natural aggregates).



Paving block made with C&D waste from Ahmedabad and Bengaluru fulfil the properties (compressive strength) as per BIS 15658:2006. Thus, paving blocks for non-traffic, light-traffic and even medium-traffic areas can be produced with C&D waste.





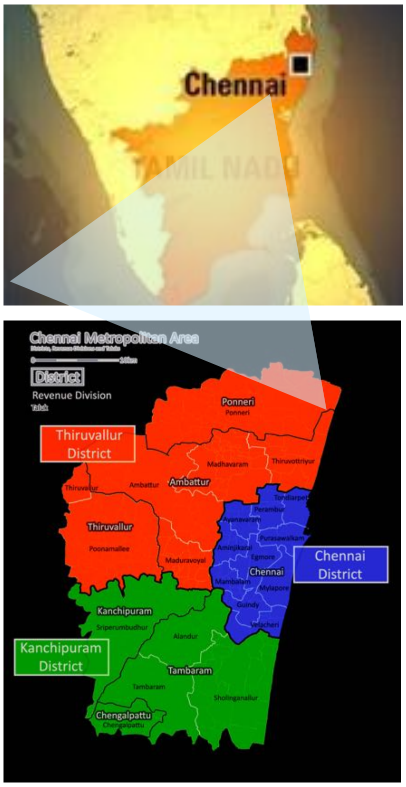
These experiments look at 100% replacement of all aggregates by C&D waste. In one case INR[14] 400/MT is assumed as the cost for collection, segregation and processing and INR 200/MT in the other. Processing is only through jaw crusher, no heavy machineries and equipment is required. The figures are based on raw material cost for hexagonal blocks. All costs are based on New Delhi figures, they will vary by place. The selling price of paving blocks in New Delhi is around INR 19/block. At INR 200/MT C&D waste, cost reduction of 28 – 33% is seen, while in the case of INR 400/MT, cost reduces by 19-22%.

[14] USD 1 = approx. INR 65

Annex 4: City Profiles

Chennai

Chennai, capital of Tamil Nadu, is one of the largest metropolitan cities in India. It is located on the Coromandel Coast at the northern end of the state. It is the oldest Municipal Institution in India, established in 1688. The city is divided into 200 wards. Chennai Municipal Corporation (CMC) included 45 wards in 2001, thus increasing the size of the city by 140%.



Map of Chennai

Chennai at a Glance

Area (Chennai City)	426 km^2
Population (Chennai City)	6.5 million
Area (Metropolitan region)	1,189 km^2
Population (Metropolitan region)	13 million
No. of Wards/Zones	200/15

Construction and Urbanisation Trends

Chennai is a very old city. Majority of the city was constructed during the British era and the post-Independence period. In current times, it is a major commercial and industrial centre. Construction activities have increased in recent times owing to population growth, urbanisation and increasing development. Apart from the new construction, existing buildings are also demolished for renovation, alteration and/or reconstruction for vertical development. The age of buildings demolished ranges from 25 to 60 years. These buildings are usually load-bearing and 1-3 storeyed.

Construction can be witnessed in greenfield areas in the newly inducted wards. Other construction activities include metro rail, housing projects and infrastructure development. Phase 1 of metro rail construction is in its final stages. Proposal for Phase 2 metro rail and monorail have been submitted. INR 1.2 billion (USD 18 million) is being invested for infrastructure development in the metropolitan area by CMDA. In addition, the Tamil Nadu Housing Board and Slum Clearance Board have proposed construction of townships and high-rise housing projects. Semi-pucca[15] houses in slums are also being demolished for construction of new houses. Some of the major projects proposed by some of the major stakeholders in Chennai are given below.

[15] Semi-permanent (traditionally made)

Construction Projects in Chennai

Tamil Nadu Housing Board	• Demolition and reconstruction of over 2,200 apartments • Construction of 2,000 new apartments
Tamil Nadu Slum Clearance Board	• Construction of 6,000 new apartments • Integrated township for over 900 tenements
Chennai Metropolitan Development Authority	• Infrastructure development worth INR 1.2 billion (USD 18 million) • Development of new market, bus stand and container truck garage

These construction activities have resulted in the generation of C&D waste. It is estimated that on an average around 2,500 tonnes of C&D waste is generated per day in CMC. Proposed construction projects will further fuel the C&D waste generation.

The common building materials used for construction include alternative materials like fly ash bricks, aerated bricks and manufactured sand (M-sand). Their popularity has increased in the past decade owing to resource shortages, especially during the monsoon. Fly ash bricks are commonly used in government construction. Very old buildings (50 years and above) are made of limestone; the use of concrete is minimal.

C&D Waste Management

The process of C&D waste management is described below.

Preparatory Processes

Preparatory processes include activities carried out after the intent to demolish a building has been established. The first step is to obtain approvals from CMC. A Demolition Application (DA) in this regard has to be submitted. Approval will be issued subject to the payment of scrutiny and demolition fees. Two types of approvals are required for the construction of buildings. One is from the planning permission which is governed by the Tamil Nadu Town and Country Planning Act, 1971 and Development Regulation Rules of Second Master Plan. Second is the building permit which is governed by the Chennai City Municipal Corporation Act, 1919 and Chennai City Building Rules.

After obtaining due permissions from CMC, the Government Departments prepare tenders for demolition. The assignment is awarded to the contractors empanelled with CMC. The payment terms are finalised and calculated on the basis of the value of salvageable material from the debris, labour and other factors. Private developers contact independent contractors for demolition.

Demolition

Buildings are usually demolished by mechanised means (earthmoving machines) after removing the valuable materials like window and door frames, unbroken ceramic, etc. Time constraints and higher labour rates are the major reasons for demolition by machinery. Steel and metal frames are removed from the structure. Remaining debris is broken down into finer particles manually or by using a concrete breaker machine.

Demolition Site (Left) and Manual Demolition (Right)

Segregation

C&D waste is segregated at site by the demolition contractors and informal sector waste dealers. The waste is segregated manually in the following streams. Whole bricks are not usually removed owing to their low quality.

- Door and window frames (wood)
- Steel rods (metal)
- Concrete/bricks/lime mortar debris

Transportation

The waste generator is required to deliver the waste from the site to the two designated C&D waste dump yards (Perungudi and Kondungaiyur) at their own expense. The waste is transported to the disposal sites by trucks / tractors by paying a minimal fee to the transporters.

Management

The common practices of C&D waste management include:

- Reuse of valuable materials
- Illegal open dumping
- Dumped in ULB designated dump yards

Valuable materials like metal and wood are sold in the secondary market and reused in construction or allied sectors.

In order to avoid transportation of the debris over long distances and to avoid the payment of waste handling charges, demolition contractors usually dump the waste in any open unfenced, unguarded plots, river banks, under bridges or even near road sides. Illegal dumping is penalised by the ULB.

C&D waste is also dumped in ULB designated dump yards. These dump yards are managed by Ramky Pvt. Ltd. on BOT basis. Waste is to be disposed after payment of waste handling fees at the dump yard. However, this waste is not treated or processed. It is used as landfill cover. The Municipal Corporation receives an average of 900 tonnes per day of C&D waste in the dump yards.

The management of C&D waste is handled under the newly formed 'Special Projects Wing'. It has tendered the work of preparing a detailed project report (DPR) for C&D waste management in the metropolitan area. Waste quantification, characterisation and existing practices are being surveyed in detail by the Indian Institute of Technology, Madras. After finalisation of the DPR, ULB would prepare a framework for proper management of C&D waste. It is also interested in recycling and reuse of C&D waste.

Cost of Materials in Secondary Market

MATERIAL	SELLING PRICE[16]
Whole bricks (red)	INR 1/brick
Metal	INR 5-10/kg
Demolition debris	INR 2,000 / truck load
Wood frames	INR 200-1,000

Illegal Dumping of C&D Waste

[16] USD 1 = approx. INR 65

Coimbatore

Coimbatore is the second largest city in Tamil Nadu. It was established during the British era. It is an important trade link between the states of Kerala, Tamil Nadu and Karnataka. Coimbatore City Municipal Corporation (CCMC) is the second largest ULB in Tamil Nadu and is famous for its initiatives on public health, sanitation and solid waste management. The urban population has increased by 140% in the last decade alone. The corporation limits widened in 2001 to add 28 new wards.

Map of Coimbatore

Coimbatore at a Glance

Area (Coimbatore City)	257 km^2
Population (Coimbatore City)	1.6 million
No. of Wards/Zones	100/5

Construction and Urbanisation Trends

Development of Coimbatore as an industrial and education centre and its location as a trade link between states has set Coimbatore on a path of continuous development. Majority of the construction occurs in greenfield areas. Flats and villas are being constructed on the outskirts of the city; however, the numbers of buildings are relatively low. CCMC is also focusing on improving infrastructure like roads and highways. The age of buildings demolished range from 25 to 50 years and they are usually one to two storeyed. These demolition activities generate around 92 tonnes per day of C&D waste. CCMC has also identified buildings that are considered unsafe with respect to fire, structure, rule violations and parking space default. It has designated 468 buildings as unsafe in 2008 and ordered their demolition. A mobile demolition / eviction team was constituted in 2009. The team has either demolished or restored the parking spaces or sealed 64 buildings in coordination.

Public and private investment is further fuelling construction in the city. Some of the major government construction projects are mentioned below:

Construction Projects in Coimbatore

Tamil Nadu Housing Board	• Demolition and reconstruction of around 1,000 flats
Tamil Nadu Slum Clearance Board	• Construction of 4,000 flats • Demolition of 246 semi-pucca[17] houses
Public Works Department	• Reconstruction of Assistant Commissioner's office of 112,000 ft^2

[17] Semi-permanent (traditionally mde)

Fly ash is commonly used for construction in the city. M-sand has also replaced natural sand, thus reducing the pressure on natural resources like sand and soil.

C&D Waste Management

The process of C&D waste management is described below.

Preparatory Processes

Approvals have to be sought from CCMC for demolition, reconstruction or renovation of buildings. Permits are issued for reconstruction and renovation purposes only. CCMC collects demolition waste handling fees while issuing reconstruction permits (INR 500/100 ft^3).

After obtaining due permissions from CCMC, the Government Departments prepare tenders for demolition. The assignment is awarded to the contractors empanelled with CMC. The payment terms are finalised and calculated on the basis of the value of salvageable material from the debris, labour and other factors. Private developers contact independent contractors for demolition.

Demolition

Buildings are usually demolished by mechanised means (JCBs and concrete breakers) after removing the valuable materials like window and door frames, unbroken ceramic, etc. Time constraints and higher labour rates are the major reasons for demolition by machinery.

Window and Door Frames Being Removed Before Demolition (Left)
and Demolition Site of TNHB Housing Units (Right)

Segregation

C&D waste is segregated at site by the demolition contractors and informal sector waste dealers. The waste is segregated manually in the following streams:

- Door and window frames (wood)
- Steel rods (metal)
- Concrete/bricks/lime mortar debris

Whole bricks are sometimes removed depending on their quality and time available for demolition.

Transportation

C&D waste management is handled by the 'Special Projects' wing of CCMC. It provides collection facility for the waste. Waste generators can contact CCMC's '*special grievance cell contact number'* for collection of waste from the generation site. CCMC doesn't levy any fees for this service. However, the collection is often delayed as the same trucks are used for collection of municipal solid waste. Therefore, generators dump the waste at the dump yard by paying private transporters.

Management

The common practices of C&D waste management include:

- Reuse of valuable materials
- Dumping in ULB designated dump yard

Valuable materials like metal and wood are sold in the secondary market and reused in construction or allied sectors. CCMC has allotted designated dump yards for disposal of C&D waste (Ukkadam and Vellalore). Notices have been issued to demolition contractors and builders about the dump yards. Illegal dumping is penalised.

In order to promote recycling of C&D waste, CCMC has proposed a recycling plant with a processing capacity of 200 tonnes per day. The waste would be recycled into aggregates and sand. Paver blocks would also be manufactured. A business plan for the sale of paver blocks has also been prepared. The proposal has been approved by the sanctioning authority. Construction of the plant is proposed to start within the current financial year.

C&D Dumping Yard (Vellalore)

Cost of Materials in Secondary Market

MATERIAL	SELLING PRICE[18]
Metal	INR 5-10/kg
Demolition debris	INR 1,000 / truck Load
Wood frames	INR 500-2,000

[18] USD 1 = approx. INR 65

Bengaluru

Bengaluru (formerly Bangalore), also known as the ‘Silicon Valley of India’ or the ‘Knowledge Capital of India’, is one of the most sought out destinations in the country owing to its climate, reputed educational, scientific and technological institutions and the booming information technology (IT) and biotechnology sectors and manufacturing industries. The recent boom in the IT sector has had an impact on the development and urbanisation of Bengaluru. The city is governed by Bruhat Bengaluru Mahanagara Palike (BBMP). It is one of the largest Municipal Corporations in India, consisting of 198 wards.

Map of Bengaluru

Bengaluru at a Glance

Area (BBMP)	2,190 km^2
Population (BBMP)	10 million
No. of Wards/Zones	198/5

Construction and Urbanisation Trends

The city is rapidly developing due to the boom in the IT sector. Majority of construction has happened in the last three decades. Huge greenfield and brownfield projects are observed all around Bengaluru. Substantial construction and demolition activities are concentrated within the city in areas like Mahadevapura, Bohmanahalli, Rajarajeshwari, etc. However, increased construction and demolition activities can be seen in different nodal regions of the city. The age of demolished buildings ranges from 15 to 40 years. Buildings constructed in the last 15 years are also renovated or demolished to create workspace for industries. The height of buildings demolished change with age. Buildings more than 25 years old are one or two storeyed, whereas 15-25 year old buildings are three to five storeys high.

The demolition waste in the BBMP region has not been calculated but an estimated 25% of the total solid waste[19] produced by weight is considered as C&D waste. Hence, the generation of C&D waste is estimated to be 875 tonnes per day.

The last decade has also seen a phenomenal change in the use of construction materials in Bengaluru. The builders’ preference has changed from red bricks to locally produced concrete bricks. Almost 90% of construction activities have shifted to concrete bricks in the last five years. Red bricks are only used for aesthetic purposes. Concrete bricks are available in different sizes varying from 4” – 8”. The use of cement in a building can be reduced by around 60% due to use of concrete bricks.

[19] As per TIFAC, 2001 study

Bengaluru is located on a granite stratum making the availability of construction aggregates easy from the huge number of quarries in the nearby locations around the city. However, the ban on mining in selected parts of the city could lead to material shortage in the near future. As a result, developers are seeking alternate construction materials.

C&D Waste Management

The process of C&D waste management is described below.

Preparatory Processes

Every person who intends to erect or re-erect a building or make material alterations or cause the same to be done, is required to obtain a licence from BBMP. In case of addition/alteration/modification to the existing building, attested copy of the previously sanctioned plan has to be submitted. However, separate permits are not issued for the sole purpose of demolition.

After obtaining due permissions from BBMP, the Government Departments prepare tenders for demolition. The assignment is awarded to the contractors empanelled with BBMP. The payment terms finalised are calculated on the basis of the value of salvageable material from the debris, labour and other factors. Private developers contact independent contractors for demolition.

Demolition

Buildings are demolished manually in the congested areas of the city. Earthmoving machines are used for demolition in uncongested areas. In both cases, wood and metal are removed before demolition. Whole bricks or tiles are not removed due to the high labour cost and limited time available for demolition.

Segregation

C&D waste is segregated at site by the demolition contractors and informal sector waste dealers. The waste is segregated manually in the following streams:

- Door and window frames (wood)
- Steel rods (metal)
- Concrete/bricks/lime mortar debris

Whole bricks are not usually removed owing to their low quality and relatively low value in secondary market. Concrete and broken bricks form a substantial part of the waste. However, the quantity of cement/concrete waste is set to increase in the future due to the changing construction practices.

Transportation

The demolition contractors are required to dump the waste in used up granite quarries outside the city. They hire transporters for this purpose.

Management

The common practices of C&D waste management include:

- Reuse of valuable materials
- Illegal open dumping
- Use as filler material
- Dumping in ULB designated dump yards

Resale Value of Materials in Secondary Market

MATERIAL	SELLING PRICE[20]
Whole bricks	INR 1/brick
Metal	INR 10-12/kg
Demolition debris	INR 2,000/ Truck Load
Wood frames	INR 500-3,000

Valuable materials like metal and wood are sold in the secondary market and reused in construction or allied sectors.

Dumping in open areas is prevalent in Bengaluru. The major reason for this is the distance of the quarries from demolition sites. Each dump yard is more than 20 kms away from the core city region. BBMP has imposed a fine of INR 5,000/tonne (USD 75) to check illegal dumping. If caught again, the trucks are seized. The State Pollution Control Board is also concerned about the distance of allocated dump yards from the city and doubts the possibility of individual citizens to dump their waste by bearing all the transportation cost.

BBMP published a list of eight designated quarries for disposal of waste in 2012. Two of these quarries (Kannur and Mallasandra Village) are currently operational. C&D waste is also used as backfill material.


Quarry for Dumping of C&D Waste (Kannur)

[20] USD 1 = approx. INR 65

In order to effectively manage C&D waste, BBMP has initiated the process of quantifying and characterising the waste. BBMP has authorised a private firm (TIDE Technocrafts Pvt. Ltd.) to prepare a DPR for C&D waste management. The study is underway. The Draft Report will be submitted to BBMP in a few months.

The materials produced by processing C&D waste can be viewed as an alternate raw material for the ailing stone crushing units in Bengaluru. The stone crushing unit operators mainly depend on granite quarries for raw materials. However, these units will be at risk of raw materials shortage when the quarries shut down due to legal issues or when material is exhausted. Nowadays, these quarries are facing legal action due to banning of granite mining within city limits. Therefore, a lot of quarries are shutting down. This affects the stone crushing units as well as the manufacturers of concrete bricks and paver blocks. Therefore, the need for alternative sources of raw materials arises.

Rock Crystals Pvt. Ltd., a stone crushing unit took the initiative to use demolition waste materials (mainly the cement concrete portion) as raw material for construction material production. Demolition waste from major construction and demolition projects are brought to the operator by the generators and the waste is being processed into aggregates of 6 mm, 12 mm, 20 mm, 40 mm, GSB (mixed aggregates for sub-base) and M-sand. The operator processes an average of 2,500 tonnes per month of C&D waste. The material produced is of competitive quality and is in demand in the market especially during monsoon season. The unit is also an empanelled member of BBMP for C&D waste management.

The initiative of Rock Crystals Pvt. Ltd. proves the acceptability of C&D waste in production of construction material aggregates. Entrepreneurs should be urged to use the waste to produce aggregates and other finished products like kerbstones and paver blocks.

Mumbai

Mumbai, the financial capital of India, is the largest city in India. The Municipal Corporation of Greater Mumbai (MCGM) is one of the biggest and richest ULB in India. Mumbai was formed by combining 7 islands. The metropolis accounts for a major portion of India's international trade and government revenue. It is also one of the foremost centres of education, science and technological research and advancement.

Map of Mumbai

Mumbai at a Glance

Area (MCGM)	437 km^2
Population (MCGM)	12 million
No. of Wards/Zones	24/6
Area (MMRDA)	4,355 km^2
Population (MMRDA)	18 million

Construction and Urbanisation Trends

The Mumbai Metropolitan Region (MMR) is one of the fastest growing regions of India. Population growth, inward migration, urbanisation and increasing economic activity is driving the growth in the construction sector. Construction activities are concentrated within the city limits. Buildings are being demolished and reconstructed for vertical development. The height of buildings demolished range from G+5 to 7. Construction in the suburbs is mostly on virgin land. Red bricks and fly ash bricks are commonly used for construction.

The total solid waste generation in Mumbai is assumed to be around 6,500 tonnes per day. About 2,500 tonnes of C&D waste is estimated to be generated. The C&D waste generation is expected to increase tremendously with the construction of metro rail, mono rail and local train services. DPR for metro line (Dahisar-Charkop-Bandra-Mankhurd) has been prepared and submitted to the State Government for approval. Mumbai Trans Harbour Link between the island city and Navi Mumbai has also been proposed. Phase – II of monorail (Wadala – Sant Gadge Maharaj Chowk) is under construction. Maharashtra Housing and Area Development Authority (MHADA) is also planning for reconstruction of 14 colonies inside the city.

C&D Waste Management System

C&D waste management system in Mumbai is explained below.

Preparatory Process

The Municipal Corporation of Greater Mumbai enacted the Construction and Demolition and Desilting Waste (Management and Handling) Rules in 2006. It requires the generator to apply for permission for demolition and submit a waste management plan. The generator has to identify a land for disposal of C&D waste and get a No Objection Certificate (NOC) from the land owner. The ULB levies a charge of INR 40,000 (USD 600) for the permits.

After getting permits from MCGM, developers/Government Departments contract demolition contractors. The value of demolition is estimated on the basis of the price of salvageable materials, cost of demolition and other factors.

Demolition

Mechanised demolition is commonly practiced after the removal of valuables. Time constraints force the contractors to demolish by machinery.

Segregation

The C&D waste is segregated into wood, steel, glass, tiles, ceramics and debris by the contractors. Whole bricks are removed only when buildings are demolished manually.

Transport

The responsibility of transportation of C&D waste lies with the contractors. They transport the remaining debris by trucks and tractors to the disposal sites. The Navi Mumbai Municipal Corporation also has authorised transporters for this purpose.

Management

The common practices of C&D waste management are:

- Sale of valuable materials
- Illegal dumping
- Dumping in identified areas

Salvageable materials like wood, glass, metal are removed from the structure and sold in the secondary market, generating revenue for contractors.

Cost of Materials in Secondary Market

MATERIAL	SELLING PRICE[21]
Red bricks	INR 1,000 – 2,000/truck
Metal	INR 30/kg
Glass	INR 1,000 – 2,000/tonne
Wood frames	INR 5,000 - 10,000

The transporters also dump the waste illegally in open areas. MCGM penalises the transporters for illegal dumping. INR 20,000 (USD 300) is levied by the MCGM. Navi Mumbai Municipal Corporation charges INR 15,000 – 50,000 (USD 227-757) for the same.

C&D waste is also dumped in areas identified by the waste generators while submitting the waste management plan. The Greater Mumbai region has not

[21] USD 1 = approx. INR 65

identified a landfill site for the disposal of waste. Waste from Mumbai is typically dumped in the suburbs. Land constraints force the developers to dump in nearby areas like Navi Mumbai, Thane, etc. Navi Mumbai has identified designated dump yards in Ulwe, CIDCO and MIDC areas.

Excavation earth also forms a substantial portion of C&D waste from the city. The earth is currently being used as filler material in construction like the new airport.

Mumbai Metropolitan Region Development Authority (MMRDA) has initiated the process of developing a C&D waste management policy for the city and its suburbs along with Ernst and Young. They are currently in the process of quantifying the amount of waste generated and conducting a feasibility study for C&D waste management in the city.

Ahmedabad

Ahmedabad, also known as the 'Manchester of India', is the largest city in Gujarat and seventh largest in India. Ahmedabad Municipal Corporation or Amdavad Municipal Corporation (AMC) was formed during the 15th century. Growth in silk and cotton industry has spurred the development of the city. The AMC area is divided into 64 wards and 6 zones, namely Central, North, South, East, West and New West. Majority of the population was concentrated within the AMC limits till the 1970s; expansion of the peripheral areas began in the 1980s. In recent decades, 180 km^2 and 80 km^2 area have been added on the western and eastern sides of the city respectively.

Map of Ahmedabad

Ahmedabad at a Glance

Area	464 km^2
Population	5.5 million
No. of Wards/Zones	64/6

Construction and Urbanisation Trends

Ahmedabad is one of the fastest growing cities in India leading to huge infrastructure development including the metro rail project. Most of the construction occurs inside the main city. Construction is also increasing in the peripheries of the city in anticipation of improved connectivity in the future due to development of roads and metro rail. The Ahmedabad Urban Development Authority (AUDA) has planned infrastructure development projects worth INR 1 billion (USD 15 million).

2,700 permits were issued by AMC for construction of buildings in 2014-15. Approximately 50% of this was for reconstruction, and 40-45 permits were issued for renovation. Currently, the height of buildings constructed range from G+5-7. The typical age of buildings demolished in Ahmedabad range between 25 to 50 years. 50 year old buildings are one to three storeyed. On the other hand, the relatively new buildings are as high as five storeys. The Gujarat Housing Board had also planned the construction of 1,048 houses in 2014. A proper study on the quantification of C&D waste has not been conducted. However, the generation is estimated to be around 700 tonnes per day. The processing plant is set up for 1,000 tonnes capacity, about 30% more than the estimated current generation.

New sets of building bye-laws are being proposed for the (older) Walled City. AMC proposes to convert unused government plots and old buildings within the Walled City areas into parking spaces. This is expected to increase demolition in the city, generating more C&D waste.

Red bricks are commonly used for construction. Fly ash and hollow bricks have also gained popularity in the last ten years. Resource shortage was not cited as an issue by the developers and government departments.

C&D Waste Management

The process of C&D waste management is described below.

Preparatory Processes

Developers have to apply to AMC for permits for reconstruction and renovation. However, permits are not issued solely for demolition.

After obtaining due permissions from AMC, the Government Departments prepare tenders for demolition. The assignment is awarded to the contractors empanelled with AMC. The payment terms finalised are calculated on the basis of the value of salvageable material from the debris, labour and other factors. Private developers contact independent contractors for demolition.

Demolition

Buildings are usually demolished by mechanised means after the removal of valuable materials like window and door frames, unbroken ceramic, etc.

Mechanised Demolition

Segregation

C&D waste is segregated at site by the demolition contractors and informal sector waste dealers. The waste is segregated manually in the following streams:

- Door and window frames (wood)
- Steel rods (metal)
- Concrete/bricks/lime mortar debris

Reusable materials like wood and metal are segregated at site. Remaining debris including bricks is transported to the disposal site. There is huge demand for demolition waste as a backfill material and for road sub-base leading to minimal dumping of C&D waste elsewhere.

C&D Waste collection site (left), C&D waste processing unit (right)

Transportation

AMC has designated 16 spots in the city where citizens can bring the waste at their own cost. The waste generated by AMC civil works is also collected at these spots. Citizens can register their complaints for collection of construction debris by phone call on AMC operated Comprehensive Complaint Redressal System (CCRS). Citizens are charged a minimum flat rate of INR 200 (USD 3) per trip for the transportation of waste from the site to the disposal points. Ahmedabad Enviro Projects Ltd. (AEP) collects the waste from these spots with their own vehicles. AMC pays the agency INR 155 (USD 2.30) per tonne for collection and management. Detailed rate chart for collection is given below.

Rates for C&D Waste Collection by AMC

WEIGHT	PER METRIC TONNE RATE	PER TRIP (MINIMUM RATE)[22]
Less than 1 MT waste		INR 200
For 1-5 MT waste (Minimum Quantity)	INR 225	INR 675
More than 5 MT waste (Large Quantity)	INR 212.50	INR 1,700

Management

The common practices of C&D waste management include:

- Reuse of valuable materials
- Illegal dumping
- Dumped in ULB designated dump yards

Cost of Materials in Secondary Market

MATERIAL	SELLING PRICE[23]
Metal	INR 15-20/kg
Demolition debris	INR 1,000/truck load
Wood frames	INR 2,000-3,000

Salvageable materials like metal and wood are sold by the demolition contractors in the secondary market. Illegal dumping is also prevalent, although to a lesser extent than other cities. Lack of information on the locations of designated dump yards is the primary reason for illegal dumping. Consultations with demolition contractors also revealed that they are under the misconception that AMC levies fees for dumping waste in dump yards.

AMC has taken a giant step in management of C&D waste by becoming the second ULB after Delhi to install and operate a C&D waste recycling unit with a processing capacity of 1,000 tonnes per day. This project is running on a PPP basis with Ahmedabad Enviro Projects Ltd. (AEP) since June 2014, where C&D waste is processed and recycled into aggregates. These aggregates are used to

[22] USD 1 = approx. INR 65
[23] USD 1 = approx. INR 65

prepare finished products including paver blocks, kerbstones, concrete tiles, prefabricated structures, etc. About 500 tiles and 2,500 paver blocks are produced every day. The finished materials sold under the trademark Nu-Earth materials are used by the ULB and local contractors in construction projects. They also sell M-sand at the rate of INR 300 (USD 4) per tonne. Currently, AEP is processing 300 tonnes per day of C&D waste on a pilot basis and is planning to increase the capacity in the near future.

C&D waste arriving at the plant is segregated into dust and brickbats. Large chunks are crushed by a jaw crusher to reduce their size. They are again segregated on the basis of size. Sieves of 10 mm and 20 mm are used. Sand of size 3-6 mm is also removed at this point. The remaining debris is again crushed and segregated. These materials are sent to the production units for manufacture of finished products.

The C&D processing plant also has facilities to reduce pollution. Mist system is provided at hoppers and crushers to reduce dust. Sand washing system is also provided where the clay particles and sand particles are segregated, dewatered and dried and again reused as sand and clay. The crushed material is also water washed by using a jet wash system. The water is reused at the site.

Patna

Patna is the capital and largest city in Bihar. It is located on the southern bank of river Ganga. The city is governed by the Patna Municipal Corporation (PMC). It is divided into 72 wards and 4 circles.

Map of Patna

Patna at a Glance

Population (City)	1.7 million
Population (Metropolitan Region)	2 million
Area	99.45 km^2
Number of Wards/Circles	72/4

Construction and Urbanisation Trends

Majority of construction activities in the city can be seen in outer areas like Danapur, Bihta, Maer, Gauri Chowk, etc. Old areas of the city like Lohanipur, Kadampur and Mithapur are extremely congested, leaving relatively less area for construction. However, the city doesn't witness substantial demolition. Mostly G+1 and load bearing buildings are demolished for reconstruction purposes. Buildings violating bye-laws are also demolished by PMC.

Buildings are primarily demolished and constructed by the Department of Building Construction (DoBC), Government of Bihar. DoBC perceives the share of private construction to be around 10% of total construction. Current major construction projects of DoBC are a museum and houses for Members of Legislative Assembly (MLA). It has also initiated the process of reconstructing its two oldest residential colonies in Gardanibagh and Shastrinagar areas of the city. Residential premises for judges of the Patna High Court, ministers and multi-storeyed building for support staff will also be constructed.

Red bricks are commonly used for construction. However, the use of fly ash is slowly increasing. DoBC has issued notifications for 50% use of fly ash bricks in government construction in a radius of 100 km from coal based thermal power plants.

PMC doesn't estimate the quantity of C&D waste generated. However, the amount of MSW generated has been estimated to be around 1,000 tonnes per day (Pandey, nd). Assuming 25% of the MSW as C&D waste[24], its volume has been estimated to be 250 tonnes per day.

[24] As per TIFAC, 2001 study

C&D Waste Management

The process of C&D waste management is given below:

Preparatory Processes

According to the Bihar Building Bye-Laws, 2014, any person who intends to erect, re-erect or make additions or alterations in any building, or demolish buildings shall apply to PMC for approval. However, this is often not followed by the developers. PMC does not issue demolition permits.

Government Departments like DoBC prepare tenders and invite bids for demolition. The bids are calculated on the basis of cost of recyclable materials like steel, door and window frames, RCC work and brick work in a building. The assignment of demolition is awarded to the highest bidder. Contractors pay the departments for demolition and removal of waste from the site. Demolition of buildings and removal of waste from the site in allotted time is the responsibility of the demolition contractors.

Demolition

Buildings are demolished manually by the contractors. Doors and window frames, steel and metal, and whole bricks are removed manually. Good quality bricks and low rates of labour are the reasons for manual demolition.

Transportation

Debris is transported from the demolition site to the disposal sites with trucks/tractors by private transporters. These transporters charge INR 1,000 (USD 15) per tractor for providing this service.

Cost of Materials in Secondary Market

MATERIAL	SELLING PRICE[25]
Bricks	INR 4 – 5
Window frames	INR 4,000 – 6,000
Door frames	INR 2,000 – 3,000

[25] USD 1 = approx. INR 65

Manual Demolition

Management

The common practices of C&D waste management are:

- Sale of valuable materials in secondary markets
- Dumping in low-lying areas

Valuable materials like wood and metal are sold by the contractors in the secondary market. Remaining debris is dumped in low-lying areas to be used as fill for future construction for which land owners typically pay the transporters. However, PMC doesn't play any role in the management of C&D waste. Dump yards have not been designated for the disposal of C&D waste. One landfill for MSW has been identified for future use.

Segregation of Materials at Site

Jaipur

Jaipur, the capital city of Rajasthan, is one of the very oldest cities in India, dating back much before the British period. The original walled city was built on a rocky plateau at the foot of the Nahargarh hills and Jhalana. With time, the city expanded to the alluvial plains. Jaipur is considered as one of the best planned developed cities in India. The buildings in Jaipur were painted pink as a symbol of hospitality during the era of kings, earning the name 'Pink City'. The tradition of painting the buildings pink continues to this day.

Map of Jaipur

Jaipur at a Glance

Area	467 km^2
Population	3 million
No. of Wards/Zones	91/8

Construction and Urbanisation Trends

The city has expanded outside the old city walls and out into the alluvial plains towards the south in recent times. Construction takes place inside as well as outside the wall. Construction outside the walled city is mostly on virgin land. Buildings are demolished and reconstructed for vertical development. Demolition is predominant in older parts of the city. However, heritage buildings can't be demolished, reducing the amount of demolition inside the walled city. Buildings more than 60-70 years old can be demolished after being deemed unsafe by the ULB. Some of the construction projects in the city include housing projects by the Rajasthan Housing Board, and the metro rail. The Rajasthan Housing Board constructed 2,219 units in 2014-15; construction of 2,590 units has been proposed in 2015-16. The metro rail project has a proposed budget of INR 8.8 billion (USD 134 million).

Buildings in Jaipur incorporate elements of Rajasthani architecture. This can be observed in old buildings as well as new structures. Stones are one of the main building materials used. In the recent times, red bricks and fly ash bricks are also being used in construction. Concrete is used for the construction of roofs. The construction industry in Jaipur does not face any resource shortage for construction materials. Sand is easily available from the Banas river bed and aggregates and stones are mined from hills around Jaipur.

C&D Waste Management

The process of C&D waste management is explained below:

Preparatory Process

Developers have to apply for approvals for demolition and reconstruction of buildings to the ULB. After obtaining due approvals, they prepare tenders for demolition of buildings. Assigned contractors have to demolish the buildings and remove waste from the site in the allotted amount of time.

Demolition

A demolition contractor takes out door and window frames followed by concrete roof slabs. After this, buildings are demolished either manually or using tools like pneumatic breakers.

Demolition (Left) and Segregation at Site (Right)

Segregation

Wood, steel, stones and bricks are removed from the buildings and segregated from concrete and broken bricks by the demolition contractors. Whole bricks are removed wherever possible. Intact stones and metals are taken out and segregated from concrete and broken bricks; stones are reused in construction of new buildings whereas metal is recycled.

Transportation

The debris is transported from the demolition site to the disposal site by transporters. Contractors pay a minimal fee for this service.

Cost of Materials in Secondary Market

MATERIAL	SELLING PRICE[26]
Whole bricks	INR 2 /brick
Stones	INR 2,000 /tractor
Metal	INR 20-25/kg
Demolition debris	INR 1,000 /truck load
Wood frames	INR 500-3,000

[26] USD 1 = approx. INR 65

Management

The responsibility for removal of waste from the site lies with the demolition contractors. They segregate valuable materials and sell them in the secondary market. The remaining debris is dumped in open areas like Delhi bypass and Jhaland road. JMC collects the waste from these sites and dumps it with MSW. JMC has not designated a dump yard for C&D waste. A portion of the debris is sold off as filler materials for low-lying areas and sub-base layer of roads.

JMC at present does not handle C&D waste. 15-20% of MSW is estimated by the ULB as C&D waste. According to its estimates, an average of 150-200 tonnes per day of C&D waste is received at the MSW collection sites. A part the MSW is processed into RDF and compost; a Waste-to-Energy plant is also being planned. Both the sites are maintained by IL&FS. C&D waste is segregated manually at these sites. JMC has also allotted 40 hectares of land for C&D waste processing & disposal. DPR is being prepared by InfraEn India Private Limited. The DPR will include aspects of quantification, characterisation and processing of C&D waste. JMC will explore PPP models for processing of waste.

Bhopal

Bhopal, also known as the City of lakes, is the capital of Madhya Pradesh. The city is comparatively old. However, major construction activities began during post-independence period. Bhopal, with its central location is very well connected to all corners of the country. With the expanded planning area of 463 km2, Bhopal stands among 15 largest cities of India.

Map of Bhopal

Bhopal at a Glance

Area	285 km^2
Population	1.4 million
No. of Wards/Zones	70/14

Urbanisation and Construction Trends

Construction occurs both on virgin land as well as by demolishing existing structures. However, there aren't any major government construction projects other than a 2,000-bed hospital. The encroachment section of the Bhopal Municipal Corporation (BMC) identifies and demolishes illegally encroaching buildings. The use of alternate building materials like fly ash bricks is very much appreciated and encouraged by the State Government and ULB. They have mandates for the use of fly ash bricks in government construction. Shortage of resources was not observed in the city.

C&D Waste Management

Construction & Demolition Waste Management in Bhopal is described below.

Preparatory Process

Approval for construction and reconstruction of buildings is given by BMC. Developers submit applications to the ULB for demolishing and reconstruction of buildings. An online building permission window has also been initiated by the BMC for quick assessment of approvals.

Demolition

The responsibility of demolition of buildings lies with the contractors. Time determines the method of demolition. Mechanised demolition is common while removing encroachments.

Demolition Site (Left) and Segregation of Bricks (Right)

Segregation

Demolition contractors segregate valuables from the waste at the site. Wood and metal is removed. Whole bricks are removed wherever possible.

Transport

Transporters dispose the C&D waste at dump sites. They levy a minimal fee for the transportation of waste from the demolition site to the disposal site. The demolition contractors, after taking out the valuable materials including wood and metal, use the C&D waste for back filling or dispose-off the waste at any low lying area, road side, unfenced property or dispose it at MSW collection points or transfer stations. C&D waste is in huge demand for back filling in Bhopal.

Cost of Materials in Secondary Market

MATERIAL	SELLING PRICE[27]
Metal	INR 30-45 /kg
Demolition debris	INR 1,000/truck load
Wood frames	INR 2,000-3,000

Management

There is no proper provision for C&D waste disposal by the ULB. The transporters dump the waste in any low lying areas. Illegal dumping at roadside, unfenced properties, etc. is also prevalent. A part of the C&D waste gets mixed up with MSW and is dumped at the dump yard at Bhanpur. BMC estimates around 50 kg of C&D waste reaches the dump yard every day. BMC penalises the transporters for illegal dumping of MSW and C&D waste. Penalties range from INR 200 – 800 (USD 3-12). C&D waste from government projects is also used for levelling of land for upcoming township at Aeropark as a temporary solution.

[27] USD 1 = approx. INR 65

Kolkata

Map of Kolkata

Kolkata, formerly known as Calcutta, is the capital of West Bengal. Located on the east bank of the Hooghly river, it is the principal commercial, cultural, and educational centre of East India. The urban agglomeration comprises of the city and its growing suburbs. The Greater Kolkata region extends from Baruipur to Bansberia, and Kalyani to Budge Budge.

Kolkata at a Glance

Area	185 km^2
Population (City)	4.5 million
Population (Metropolitan region)	14 million
No. of Wards	144

Construction and Urbanisation Trends

Kolkata is an old city. Construction activities are concentrated in the fringe areas of the city, where much high-rise construction can be seen. Old buildings can be seen in parts of northern Kolkata.

Approximately 4,000 construction permits are given out each year by the Kolkata Municipal Corporation. One-third of these buildings are constructed on virgin land, while two-thirds are reconstructed after demolition. Buildings are mostly demolished for reconstruction purposes or conversion to high-rise buildings. Mostly G+1-2, load-bearing buildings are demolished. 50 buildings were constructed by the PWD in 2014-15. 8,980 houses have also been constructed by the Kolkata Metropolitan Development Authority (KMDA) under IHSDP for slum dwellers. Construction in the suburbs and satellite townships is mostly on virgin land.

C&D Waste Management System

The process of C&D waste management is explained below:

Preparatory Process

The first step is to obtain approvals from the Kolkata Municipal Corporation (KMC). In case of reconstruction or alterations, developers need to apply for sanction and submit revised building plans to the ULB. Every person who intends to erect a new building on any site, whether previously built upon or not, or re-erect or make additions to or alteration of any building has to apply for sanction by giving notice in writing to the Municipal Commissioner. In cases of mandatory demolition, KMC issues notices to building owners before demolition. The KMC serves Stop Work notice after detecting illegal construction and deals with it under section 400 (I) or 400 (8) of KMC Act 1980. However, no permits are issued solely for demolition. Developers need to inform KMC 15 days prior to demolition, although this is not always strictly followed.

After obtaining due approvals, they prepare tenders for demolition of buildings. Assigned contractors have to demolish the buildings and remove waste from the site in the allotted time.

Demolition

A demolition contractor takes out door and window frames followed by concrete roof slabs. After this, buildings are demolished manually. Low rates of labour and good quality of bricks are the major reasons for manual demolition.

Segregation

Wood, steel, and bricks are removed from the buildings and segregated from concrete and broken bricks by the demolition contractors at the site.

Transportation

The remaining debris is transported from the demolition site to the disposal site by transporters. 660 collection points are designated by the KMC. C&D waste dumped at the collection points will be transported to the dump yards by the ULB. KMC charges INR 1,250 (USD 19) to developers per tonne per trip for transportation and dumping, if carried by KMC vehicles. One can also dump the waste directly to the dump yard, in which case INR 550 (USD 8) per tonne per trip has to be paid to KMC.

Cost of Materials in Secondary Market

MATERIAL	SELLING PRICE[28]
Whole bricks	INR 4-5/brick
Doors	INR 5,000 – 6,000
Half bricks	INR 600-700 / truck
Steel	INR 25 /kg

Management

The responsibility of removal of waste from the site lies with the demolition contractors. They segregate valuable materials and sell them in the secondary market. Half bricks are used as sub-base layer for roads. The remaining debris is either illegally dumped in open areas or dumped at

[28] USD 1 = approx. INR 65

collection points. KMC collects the waste from these areas and dumps it in the municipal landfill at Dhapa. This landfill is encroaching a Ramsar[29] wetland and cannot be expanded. Therefore, another landfill at Rajarhat (20 acres) has been identified. However, KMC has cited land constraints even in the proposed location.

KMC estimates 400 tonnes of C&D waste generation per day. However, the total C&D waste collected at the landfill was 57,900 tonnes in 2014. According to KMC, the waste generation per capita has remained the same over the last decade. A slight decline in population in the city proper has been the major reason.

[29] Protected wetland according to Ramsar Convention, 1971

Delhi

Map of Delhi

Delhi, the national capital, has a population of more than 16.7 million. Delhi is one of the most populous cities in the country. The population is expected to further increase in the future. As per Delhi Development Authority's Master Plan, roughly 23 million will reside in Delhi by 2021. The functions of Municipal Corporation of Delhi (MCD) are derived from the Delhi Municipal Corporation Act 1957 (DMC Act) and its amendments. MCD has been trifurcated into North Delhi (NDMC), South Delhi (SDMC) and East Delhi Municipal Corporation (EDMC).

Delhi at a Glance

Area	1,483 km^2
Population	16.7 million
No. of Wards/Zones	272/12

Urbanisation and Construction Trends

Growth in the construction sector has been fuelled by the relaxation given in building norms as a result of promulgation of Master Plan of Delhi-2021 in term of extra coverage, FAR and number of storeys. Construction activities are increasing not only to meet the demand for more housing units but also to fetch higher returns on the land in possession. Increase in FAR along mass rapid transport corridors is also expected to increase the generation of C&D waste.

C&D waste is generated by three types of generators. Waste from residential waste generators is produced due to renovations or alterations and reconstruction of buildings. Developers (residential, commercial and infrastructure) are the second type of generators. Government Departments involved in the construction of roads, bridges and other infrastructure projects are the third type of waste generators. It has been estimated that Delhi produces 4,600 tonnes per day of C&D waste. Approximately 1,000 tonnes per day of C&D waste is generated daily in SDMC alone.

C&D Waste Management System

C&D waste management in Delhi is described below.

Preparatory Process

Approval for construction and reconstruction of buildings has to be taken from MCD if the area of the plot is more than 100 m^2. Small residential plots of size up to 100 m^2 have been exempted from sanction procedures. The proponents will only have to furnish the requisite information in a simplified one page format to the concerned urban body and go ahead with the construction. The validity of this submission will be three years and if required, a fresh submission may be made thereafter.

After obtaining due approvals, waste generators prepare tenders for demolition of buildings. Assigned contractors have to demolish the buildings and remove waste from the site in the allotted time.

Demolition

Demolition activity is undertaken by demolition contractors who bring their own equipment and labour and transport the residual waste. The value of demolition is decided based on the recoverable value of recycled materials – steel, wood, glass, pipes etc. Buildings are demolished manually to recover bricks. The remaining debris is removed by JCB machines.

Segregation

Demolition contractors segregate valuables from the waste at the site. Wood and metal is removed. Care is taken to remove whole bricks for reuse at site or sale in the secondary market.

Transport

C&D waste is transported through 3 types of transport contractors. Tier 1 transporters use animals (mules, donkeys, and horses), cycle trolleys and tractor trolleys to transport C&D waste. The animal based transportation can be primarily seen in congested city areas like Old Delhi. Animals and cycle trolleys can carry small quantities of 100 - 150 kg. They transport C&D up to maximum distances of 5 to 7 km. Tractors carry loads of 1.5 - 2 tonnes. They transport C&D waste over a distance of 10 km. Tier II transporters are private truck operators who transport waste up to 15 km. Tier III transporters are contracted by the MCD for C&D waste removal from authorised dumpsites and unauthorised locations. Many waste generators also employ private contractors to transport the waste in dumpsites.

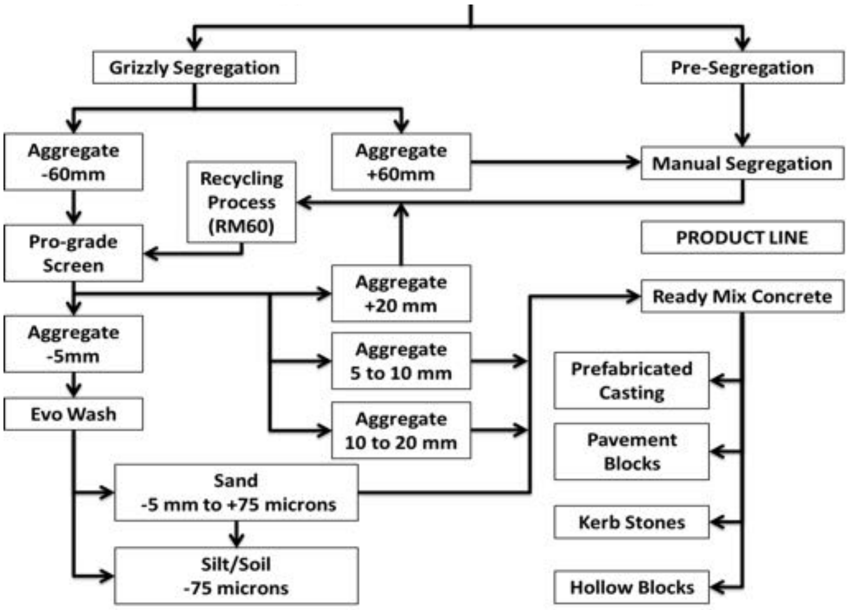
Management

C&D waste is managed in the following manner in the city.

C&D waste has always been dumped illegally at roadsides, forested and low-lying areas, as well as the Yamuna river bed. However, dumping in the river bed has reduced in recent years due to the action taken by the National Green Tribunal. Waste is dumped illegally to avoid paying transportation and landfill disposal costs.

C&D waste is also disposed without any processing at the landfill sites in Ghazipur, Balaswa and Okhla. Delhi has 168 designated collection points for C&D waste.

C&D Waste Processing in Burari, Delhi



Delhi has been a pioneer in the processing and recycling of C&D waste. In collaboration with the Delhi Municipal Corporation, a pilot project was developed by IL&FS Environmental Infrastructure & Services Ltd (IEISL) in 2010. This public private partnership (PPP) has been initiated for 10 years to demonstrate the potential of a scientifically managed process for the collection and recycling of C&D waste in Delhi. In the processing facility, 2,000 tonnes per day of waste is collected from three designated zones of Delhi - Karolbagh, Sadar - Paharganj and City. 27 collection points were identified for waste collection. Later, this was increased to 48. The facility recovers about 97% of the materials from waste for processing. Treated sewage water is used for wet processing. The C&D waste is thereafter recycled into aggregates at the waste management facility, which is in turn converted to Ready Mix Concrete (RMC), pavement blocks, kerbstones and concrete bricks. 1,200-1,400 bricks can be produced daily in an 8 hour shift.

Products have been tested in various laboratories and found to be suitable for the specific purposes. These products are sold as per the Schedule of Rates of the Government. The Delhi Government has issued orders for mandatory use of these products in construction. For example, these bricks are currently being used in the construction of Supreme Court offices near Pragati Maidan.

The pilot initiative in Burari has proved the viability of such processing facilities. The Delhi government plans to set up more such facilities in different zones of the city so that a facility is close to any future C&D site. Another plant at Shastri Park, East Delhi with a capacity of 500 tonnes per day was commissioned in October 2015. SDMC has also proposed a plant at the Ghummanhera site in Najafgarh Zone.

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