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Quantification of the Construction cost savings by using recycled material derived from Construction and Demolition Waste

Varsha U[1] & Dr. M. Kranti Kumar[2]*
[1]Post Graduate Student, Department of Architecture, School of Planning and Architecture, Vijayawada – 520008, India
[2]Assistant Professor, Department of Architecture, School of Planning and Architecture, Vijayawada – 520008, India

ABSTRACT
The current process of construction and its related activity in the country generates huge volumes of waste and it is estimated that India generates an estimated 150 million tons of Construction and Demolition waste from construction, renovation and demolitions every year [1] and unofficial estimates of the total waste generated in the country put the figure at three-five times more than the official estimate. It was found that India recycles just one per cent of its Construction and Demolition Waste (CDW) in a survey by CSE on August 25, 2020.By analyzing the composition of various materials in the CDW stream in our country, ways of recycling, reusing manage those major contributors by can be identified. By studying the status of various CDW management systems in the country, their by-products we can understand the options to incorporate the waste generated, back into the construction industry, and the permissible levels and standards for the same. Cost savings incurred in construction by following the available permissible CDW substitutions, and latest research in the construction materials using CDW byproducts can be quantified, to get a clear picture of the benefits possible. The need for further innovations and possible scope and use for waste materials are understood. With the current shortage of dwelling units in India, and the volume of CDW generation, incorporating the CDW materials in construction of the same be economically and environmentally beneficial.

Keywords: *Construction and demolition waste; Construction waste management; Construction waste reuse; Construction industry.*

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INTRODUCTION

Construction and Demolition (C&D) waste constitutes any waste that is resulting from construction and allied activities, be it remodeling, redevelopment, demolition, repair, rebuilding of any structure like houses, roads, dams, and other infrastructure developments etc. [2]. This stream mainly comprises building materials, debris and rubble [2]. This kind of waste generated was classified into six categories based on their derivation source i.e. design, procurement, material handling, operation, residual related and other[3]. The global statistical reports state that the construction industry is considered as one of the bulk generators of waste and this contributes about 40 % of the waste that goes to landfills nationally. This waste stream not only includes waste or unusable products but also surplus of unused building materials, contaminated material which ultimately result in energy losses as good useable materials are not recycled and new materials have to be procured again for various uses[4].

Scope for Construction waste Management in India

Construction and demolition (C&D) waste has become an important issue not only from the perspective of cost efficiency but also due to its adverse effect on the environment. Exploring the possible uses for these materials in the current context could help reduce this huge proportion of waste and divert it back into the useable sources to reduce the overall impact[5]. Studying the current waste management methods and situation in the country could help us identify the major contributors and identify the products the waste products are recycled as and the proportion of waste that gets recycled in to useable product. Research on the by-products of this handling centers and the construction norms for use of recycled materials in the country would shed light on the extent of suitability and reduction of waste by directly cutting down on the load of the natural resource demand on the natural environment and the waste generated in the acquisition process of the same. Identifying a suitable use and the possible financial and practical benefits of the recycled material helps could in return motivate the involved stakeholders to better practice proper waste disposal methods and improve the market for recycled construction material. A clear picture of the extent of benefits by using the same in major constructions could help towards a better management of the waste. Resource depletion due to excessive sand mining and natural material sourcing which are the major factors of immediate concern due to the rising demand for the resources to satisfy the demands of infrastructure and housing development owing to extreme shortage and the need to construct the same in the current context.

AIMS AND OBJECTIVES

The study objectives can be structured in the following sections

1) Identify the largest contributors to the construction and demolition waste stream in the country by weight and volume that is generated.
2) Identify the byproducts generated from the CDW handling units in the country and their applications
3) Identify the major categories of building materials that are most suitable and the Permissible levels of incorporation of recycled materials and CDW management bye products.
4) Assess and identify the typology and area of construction with a Case study analysis.
5) Discussion and drawing conclusions for the benefits or savings obtained.

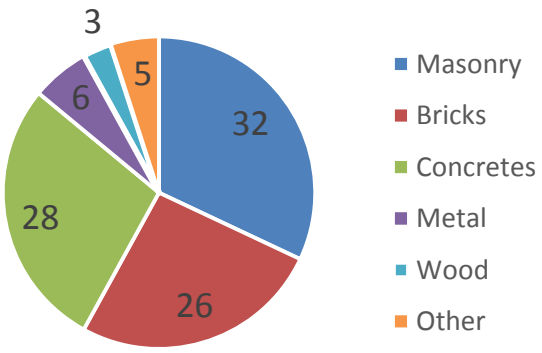
METHODOLOGY

1) Literature review on the existing data and Graphs and data available about the volumes of waste generated, their classifications, and the collection strategies followed and derive the major or largest volume of contributors to the CDW stream.
2) Study the various CDW handling facilities that are operational in the country, the daily handling capacities, typology of accepted intake, their outcome or end products that are derived from this CDW recycling and repurposing.
3) Studying the new research on ways to reduce the use of natural resources in construction by recycled material substitutions, applications of CDW generated building materials and identify the most suitable and feasible building materials, their permissible usage levels under various typologies of construction.
4) Selection of a suitable case study by considering a suitable building typology and understanding the leanings from above
5) Analyzing the various components of the case study building with reference to the financial implications or benefits by applying the findings and substituting selected natural materials and with recycled or sourced materials and Drawing conclusions.

LITERATURE REVIEW

Construction waste Compositions

The constituents of C&D waste generated and their respective quantities vary on regional basis. The general proportions of construction and demolition waste in the country consists of Soil, Sand, Gravel that accounts for Bricks, Masonry, Concretes, Metal , Wood and other material in the order of respective volumes, The percentage wise proportions of the same can be given by the figure below[1]. It is also noted that of this waste stream Things like glass, tiles, iron, metal, wood are sold for reuse and recycled. The rest of the components comprise Brick & masonry, soil, sand & gravel account for a major portion with over 60% of total waste in the generated stream[1]. This majority is sent to landfills and certain portion that reaches the recycling facilities gets recycled and processed into recycled aggregates, M sand, Construction Dust, Paving blocks etc[6].



(F: 1)

C&D waste management in India

Based on the principles of reuse and recycling and towards a planned and organized processing and disposal of the generated waste a set of rules were implemented by the government in India “The C&D Waste Management Rules 2016” with primary focus on management of C&D waste [2].

It provides a guideline for the exclusive set of duties and responsibilities for a waste generator, and the duties or roles that they hold when it comes to the disposal, and basically states that the disposal or handover of the waste to the respective authority will be the sole responsibility of the waste generator, and the logistical fees involved till the collection point would be borne by the producer [7].

Specifies the methods and classifications to be followed by the generator, for acceptable processing and reduction of contamination, for ultimate processing at the handling facility.

A provision for reporting the violations has been made easy and the fines that would be levied have also been addressed to motivate the individuals to perform their duties wrt the disposal

Applications of CDW derived and recycled materials

The various methods and exploring the potential for use of C&D waste processing products is not a new concept and this reuse has been noticed in as early as post -Second World War era [8]. These possible uses in the current context that are majorly observed include

1) Use of construction debris derived Recycled aggregates up to an extent of 20–50% in concrete, Construction blocks, pavers, tiles etc.
2) Manufactured soil used as a substitute of excavated soil for landscaping purposes, as raw material for RMCs and in construction sites can be mandated for certain constructions.
3) Substitution of the usage of primary aggregate with recycled aggregate materials in road construction applications which also further reduces the thickness of asphalt layer (Ref).
4) The Material derived from recycled C&D wastes, comes with an added benefit of cheaper prices as compared to the price of primary Natural material with similar chemical, mechanical and physical properties. This overall cost benefit can also be a notable motivator to improve the re-introduction of wastes in construction.

The comparative benefits of using construction waste as raw material vs naturally sourced materials and the effects and impacts are given as:

Costs and Risks		NRM	CDW	Remarks
Procurement	Cost	Medium	Low	CDW cheaper than quarry stone (for optimal collection distance)
	Risk	Low	High	Lack of supply chain - institutional support required
Processing	Cost	Medium	Medium-High	Higher costs owing to manual and automated separation required prior to CDW processing
	Risk	Low	Medium	Higher risks owing to technological unfamiliarity; risk of machinery damage due to undesirable substances in waste
Transaction	Cost	Medium	High	More complex transactions involved in CDW - risks of non-compliance involved since sector is immature
	Risk	Low	High	Informality of arrangements in the CDW sector implies the requirement of better enforcement of BBMP norms
Social/ Environmental	Cost	Medium	Negative	The social costs of virgin stone quarrying need to be internalised by appropriate institutional and behavioural changes
	Risk	Medium-High	Low	CDW procurement and processing is socially risk-less compared to quarry operations

(T: 1)

Applications of CDW in construction

Main components of construction that are derived from CDW recycling and repurposing plants can be in the form of Recycled concrete aggregate, Manufactured sand, Concrete paver blocks, from the processes involved in production of components. Structural and practical suitability of using these by products has been proved by various researchers.

Utilization of M sand instead of natural River sand in construction does not affect the compressive strength of concrete and M sand can be used as a best alternative for River sand [9]. The workability changes from addition of m sand can be compensated with the help of plasticizers and the overall integrity and compressive strength of the concrete can be achieved [10].[11]Hence we can replace the natural sand in concrete by M sand that would help reduce the construction cost and load on natural sand.

Substitution of m sand in place of natural sand was also found to increase the flow of cement mortar and hence it can be used with adjusted water cement ratio by reducing the amount of water in mortar preparation by partial or full replacement of M-sand can be recommended in plastering mortar [12].

Table Below (T: 2) shows the permissible quantities for substitution of RCAs in a typical building using less than M25 grade of concrete.

Sr. No.	Type of Aggregate	Maximum Utilization		
		Plain Concrete Percent	Reinforced Concrete Percent	Lean Concrete (Less than M-15 Grade) Percent
(i)	Coarse aggregate			
(a)	Recycled concrete aggregate (RCA)	25	20 (Only up to M-25 Grade)	100
(b)	Recycled aggregate (RA)	Nil	Nil	100
(ii)	Fine aggregate			
(a)	Recycled concrete aggregate (RCA) (See Note 1)	25	20 (Only up to M-25 Grade)	100

[1]

(T: 2)

Cost benefits in terms of material purchases by utilizing the approved amounts can be given by the graph below and comparing the costs from the reference table below for respective costs we can calculate possible costs per category.

			NRM	CDW
Dsr num	material	units	Dsr cost	Cost
983, 278	Coarse sand (zone III)	cum	1500	
	Fine sand (zone IV)	cum	900	741
287 , 279	Brick Aggregate (Single size) : 40 mm nominal size	cum	650	650
293	Stone Aggregate (Single size) : 40 mm nominal size	cum	1300	
295	Stone Aggregate (Single size) : 20 mm nominal size	cum	1400	957
297, 281	Stone Aggregate (Single size) : 10 mm nominal size	cum	1350	957
8686	Precast C.C. Kerb stone M - 25	cum	5600	
7237	Precast chequered cement tiles 22 mm thick medium shade	sqm	335	

[13]

(T: 3)

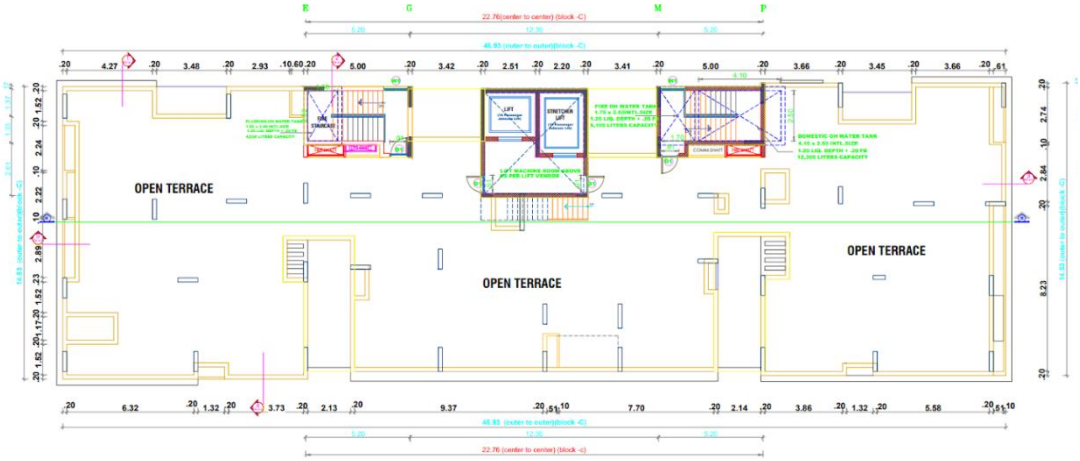
Case Study:

A case study of an Residential apartment building tower of G+ 11 floors and a site area of 2035 Sqm and a built up area of 6624 Sqm Ground coverage of 613 Sqm Is considered for the analysis.

Typical Floor Plan:

(F: 2)

Terrace floor plan



(F: 3)

The cost of construction of the cold structural shell, Where CDW substitutions are possible as shown in the table the rates as discussed in the Table (3) are calculated, by referring to the CPWD analysis of rates of construction 2021.

Using the allowable substitutions of naturally source materials with the CDW the following Calculations can be made, per each category of construction.

1) Piling

Pile foundation of grade m25 following the acceptable substitution is of 20 % NRM. The labour rates and other expenses are considered the same and the values obtained are as follows.

CATEGORY & CODE	ACTIVTY DESCRIPTION	UNITS	RATE		QUANTITIES	AMOUNT	AMOUNT
Pile Casting	**Boring, providing and installation bored cast-in-situ reinforced cement concrete piles of grade M-30 of 500mm dia and length below the pile cap, to carry a safe working load not less than specified, excluding the cost of steel reinforcement but including the cost of boring with bentonite solution and temporary casing of appropriate length for setting out and removal of same and the length of the pile to be embedded in the pile cap etc. by Bailer and chisel technique by tripod and mechanical Winch Machine all complete, including removal of excavated earth with all its lifts and leads**						₹75,488
20.2.2	Pile (500 mm dia)	1 metre pile	2274.25	2258.07	4665.50	1,06,10,513.38	₹1,05,35,026
-	pile test integrity test	each	708.00	708.00	105.00	74,340.00	₹74,340
						1,06,84,853.38	₹1,06,09,366

[13]

(T: 4)

Hence it can be noted that 0.75 % cost of the pile construction can be reduced by the above process.

2) PCC

For Plain cement concrete in non-structural works it's noted that the acceptable substitution is of 100 % of NRM. The labor rates and other expenses are considered the same and the values obtained are as follows.

CATEGORY & CODE	ACTIVTY DESCRIPTION	UNITS	RATE		QUANTITIES	AMOUNT	AMOUNT
PCC	**4.1 Providing and laying in position cement concrete of specified grade excluding the cost of centering and shuttering - All work up to plinth level : 4.1.11 *1:5:10 (1 cement : 5 fine sand derived from natural sources : 10 graded stone aggregate 40 mm nominal size derived from natural sources)***						₹24,660
4.1.11	pile cap	1 cum	5,660.45	5,418.21	22.97	1,30,004.69	₹1,24,441
4.1.11	plinth beam	1 cum	5,660.45	5,418.21	10.88	61,585.70	₹58,950
4.1.11	basement	1 cum	5,660.45	5,418.21	42.75	2,41,984.24	₹2,31,628
4.1.11	Stilt	1 cum	5,660.45	5,418.21	25.20	1,42,643.34	₹1,36,539
						5,76,217.96	₹5,51,558

[13]

(T: 5)

Hence it can be noted that 4.28 % cost of the PCC construction can be reduced by the above process.

3) RCC

Concrete of grade M25 following the acceptable 20 % NRM substitution following values can be obtained. By volumetric substitution of natural materials used in the mortar for 20mm aggregate, 10 mm aggregate and Natural river

sand in the concrete mix and with the required additives of admixtures, while the labor rates and other expenses are kept constant, we can calculate the cost of concrete as given in the table T: 6

CATEGORY & CODE	ACTIVTY DESCRIPTION	UNITS	RATE		QUANTITIES	AMOUNT	AMOUNT
Concrete M25	5.33 Providing and laying in position ready mixed or site batched design mix cement concrete for reinforced cement concrete work excluding the cost of centering, shuttering, finishing and reinforcement - 5.33.1 All work up to plinth level- 5.33.2 upto 5th floor- 5.33.3 For evry 4 floors after 5th :5.33.1.2 Concrete of M25 grade with minimum cement content of 370 kg /cum						5.2%
5.33.1.2	Retaining wall	1 cum	8,683.80	8,155.20	88.18	₹ 7,65,738	₹7,19,126
5.33.1.2	Basement floor	1 cum	8,683.80	8,155.20	85.50	₹ 7,42,465	₹6,97,270
5.33.1.2	pilecaps	1 cum	8,683.80	8,155.20	123.85	₹ 10,75,473	₹10,10,007
5.33.1.2	plinth beams	1 cum	8,683.80	8,155.20	15.90	₹ 1,38,072	₹1,29,668
5.33.2.2	stilt columns	1 cum	10,306.19	9,777.59	31.66	₹ 3,26,253	₹3,09,519
5.33.2.2	stilt slab	1 cum	10,306.19	9,777.59	93.30	₹ 9,61,567	₹9,12,249
5.33.2.2	lift wall (0-5 floors)	1 cum	10,306.19	9,777.59	41.76	₹ 4,30,386	₹4,08,312
5.33.2.2	columns (1-5 floor)	1 cum	10,306.19	9,777.59	110.16	₹ 11,35,329	₹10,77,099
5.33.2.2	slab (1-5 floors)	1 cum	10,306.19	9,777.59	447.00	₹ 46,06,865	₹43,70,581
5.33.2.2	beams (1-5 floor)	1 cum	10,306.19	9,777.59	210.83	₹ 21,72,801	₹20,61,360
5.33.2.2, 5.38	lift wall (6-9 floor)	1 cum	10,587.14	10,058.54	27.84	₹ 2,94,746	₹2,80,030
5.33.2.2, 5.38	coumns (6-9 floor)	1 cum	10,587.14	10,058.54	88.13	₹ 9,33,023	₹8,86,439
5.33.2.2, 5.38	slab (6-9 floors)	1 cum	10,587.14	10,058.54	357.60	₹ 37,85,960	₹35,96,932
5.33.2.2, 5.38	beams (6-9 floors)	1 cum	10,587.14	10,058.54	168.66	₹ 17,85,626	₹16,96,473
5.33.2.2, 5.38	coumns (10-11 floors)	1 cum	10,868.09	10,339.49	44.06	₹ 4,78,891	₹4,55,599
5.33.2.2, 5.38	slab (10-11 floors)	1 cum	10,868.09	10,339.49	178.80	₹ 19,43,214	₹18,48,700
5.33.2.2, 5.38	beams (10-11 floors)	1 cum	10,868.09	10,339.49	84.33	₹ 9,16,506	₹8,71,929
5.33.2.2, 5.38	lift wall (10-12 floors)	1 cum	10,868.09	10,339.49	20.88	₹ 2,26,926	₹2,15,888
5.33.2.2, 5.38	terrace col, ohts, etc	1 cum	10,868.09	10,339.49	33.75	₹ 3,66,765	₹3,48,927
					2252.18	2,30,86,606	₹2,18,96,107

[13]

(T: 6)

Hence it can be noted that 5.2 % cost of the concrete construction can be reduced by the above process. It can also be noted that in case of low rise buildings higher cost savings are obtained.

Where in below plinth works 6 .1% reduction can be observed and 5.13 Percent savings can be noted for concreting structures up to 5th floor level. The Cost reduction reduces with each additional floor after 5th level. And percentages for each 4 floors can be found as 4.99 % and 4.86 % respectively.

4) Plastering

For plastering and finishing works the naturally sourced sand used in the cement mortar can be substituted by 100 % in the entire building. The labor rates and other expenses are considered the same and the values obtained are as follows.

CATEGORY & CODE	ACTIVTY DESCRIPTION	UNITS	RATE		QUANTITIES	AMOUNT	AMOUNT
Plastering	13.2.1) 15 mm cement plaster on the rough side of single or half brick wall of mix 1:4 (1 cement: 4 fine sand): & 1:6(1 cement: 6 fine sand) 13.22) Extra for plastering exterior walls additional height of 3 m of height more than 10 m from ground level 13.21) Extra for providing and mixing water proofing material in cement plaster work						1.0%
13.2.2	Interior	1 sqm	324.30	320.40	16236.94	52,65,639.64	52,02,315.58
	Interior						1.2%
13.2.1	Exterior upto 2nd floor	1 sqm	339.70	335.80	1218.1	4,13,788.57	4,09,037.98
13.2.1& 13.22	Exterior 3 floor	1 sqm	412.5	408.60	489.26	2,01,819.75	1,99,911.64
13.2.1& 13.22	Exterior 4 floor	1 sqm	485.3	481.40	489.26	2,37,437.88	2,35,529.76
13.2.1& 13.22	Exterior 5 floor	1 sqm	558.1	554.20	489.26	2,73,056.01	2,71,147.89
13.2.1& 13.22	Exterior 6 floor	1 sqm	630.9	627.00	489.26	3,08,674.13	3,06,766.02
13.2.1& 13.22	Exterior 7 floor	1 sqm	703.7	699.80	489.26	3,44,292.26	3,42,384.15
13.2.1& 13.22	Exterior 8 floor	1 sqm	776.5	772.60	489.26	3,79,910.39	3,78,002.28
13.2.1& 13.22	Exterior 9 floor	1 sqm	849.3	845.40	489.26	4,15,528.52	4,13,620.40
13.2.1& 13.22	Exterior 10 floor	1 sqm	922.1	918.20	489.26	4,51,146.65	4,49,238.53
13.2.1& 13.22	Exterior 11 floor	1 sqm	994.9	991.00	489.26	4,86,764.77	4,84,856.66
13.2.1& 13.22	Exterior Terrace	1 sqm	1067.7	1,063.80	230.33	2,45,923.34	2,45,025.05
13.2.1 & 13.21	OHT Interior	1 sqm	399.7	395.80	44.50	17,786.65	17,613.10
13.9	OHT, Head Room	1 sqm	339.70	335.80	427.96	1,45,378.01	1,43,708.97
						39,21,506.93	38,96,842.43
	External						0.6%
					22561.17	91,87,146.57	90,99,158.01
	Total						1.0%

[13]

(T: 7)

From the calculations above it can be observed that by the substitution process.

i) 1.2 % cost of the internal plastering can be reduced
ii) 0.65 % of the external plastering cost can be reduced

The above categories can be added up and the overall savings of the building can be found. And the total possible saving can be derived upon.

Observations:

The total cost of construction of the tower excluding the services is given as 11.13 crores.And observations can be summarized per category as given by the table.

	NRM	CDW	Diff	Percentage
Structure	₹7,22,94,252	₹7,09,48,982	₹13,45,270	1.86%
Finishes	₹1,22,33,612	₹1,21,45,624	₹87,989	0.72%

(T: 8)

CONCLUSIONS

1) Maximum Cost reduction can be observed in the Concrete cost at 5.2 % cost and followed by savings in PCC material at 4.28 %.
2) Mortar used in plastering can be modified for improved cost and contributes to overall reduction of construction related waste.
3) In case of Low cost housing further incorporation of CDW products is possible for tiling, flooring and paving options.
4) Maximum savings can be possible in case of how rise housing or residential buildings of in Structural costs.

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