Optimizing energy through on-site reuse and recycle construction waste in residential project – A Case Study of Pune

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ABSTRACT

India is a growing to become world's third largest construction market by 2025. It is also accounting for 11% of India's GDP after agriculture in country. Construction material waste is generated during any new construction, renovation, demolition of buildings and infrastructure projects. Virgin material, after extraction, cannot be used in its original state for building construction. It undergoes processing, which involves consumption of energy in terms of manufacturing or finishing, transportation, etc. The construction waste is a by-product of construction process. Construction waste has embodied energy and also needs energy for its disposal in term of transfer to dumping sites, which affect the environment adversely.

The study on practices and procedures to reuse the waste on-site and maximize use of recycled material is important with a view to minimize possible usage of virgin material in construction process. For the purpose of this research, the construction process and practice of residential projects is considered. As 80% of the residential projects in India are executed through conventional construction process, it is imperative to observe and recommend appropriate methods of construction activity to optimize energy usage. Categorically large infrastructure project and large scale housing projects are not considered, since it has an alternative of pre-cast / prefab construction method. It is beyond the scope of this research

The research paper focuses on the energy involved in construction waste and deriving strategies for reusing and recycling of the same. It also identifies the causes of generation of construction waste along with the quantity of waste generated on-site at different stages of conventional construction process. This study will helps to encourage possible on-site practices and procedures to minimize the waste and to utilize the embodied energy involved in construction waste.

INTRODUCTION

India is growing to become the world's third largest construction market by 2025, as per a study by Global Construction Perspectives and Oxford Economics[i]. Today the construction industry is the second largest industry of the country after agriculture and it is accounting for 11% of India's GDP[ii]. The Indian economic environment and system and procedures would further enhance construction industry, as it provides the basic physical infrastructure for the nation as well as other industries.

In India, construction industry is not just the fastest growing industry but largest in terms of investment, volume of natural resources consumed, volume of materials and products manufactured, employment generated and environmental impacts, etc. Along with development, construction industry carries several challenges like emissions to air, land contamination, noise pollution, waste disposal and discharges to water[iii].

Due to huge consumption of construction materials, huge amount of construction waste is generated during construction.

The construction and operation of the built environment has been estimated to account for

- *12-16% of fresh water consumption;*
- *25% of wood harvested;*
- *30-40% of energy consumption;*
- *40% of virgin materials extracted;*
- *20-30% of greenhouse emissions;*
- *40% of the total waste stream of countries, 15-30% of which ends up in landfill sites;*
- *Up to 15% of purchased materials at jobsite ending up as waste.[iv]*

From above percentage, it is seen that the problem of landfill waste needs to be given top priority and has to be tackled as soon as possible, by finding strategic solutions to the problem. The construction waste dumped on landfill site, leads to soil pollution which affects soil fertility and also leads to sub-soil water pollution. Random dumping of these wastes leads to air pollution and degrades the air quality.

The construction waste involves energy in extraction, manufacturing process, transportation to construction site, construction process, finishing and transportation to the landfill sites. Construction industry needs to address this issue and re-examine their construction processes and practices in this regard.

METHODOLOGY

This paper explains the need of optimizing energy in construction projects and establishes the relationship of embodied energy in building material and the los of same through construction waste. It further discusses material losses on construction site in Indian context through having an adverse effect on embodied energy and correspondingly cost of the project.

This paper quantifies construction waste generated at different stages of construction process through case study method. The method adopted for understanding the market practices of waste handling is through interviewing professionals like Project management consultants, Architects, Civil Engineers, and Contractors working on the site. The outcome of the interview is tabulated in percentage of waste material with respect to the total quantity of specific material purchased on site for concerned project..

The study also quantifies the wastage through cost implication and also in terms of total embodied energy of the material. It then suggests strategies and recommendations for construction practices to reduce construction waste generation and also recomends procedures for reuse of construction waste material.

The research then identifies the quantum of the material that can be reused and reclyed on site and make practicing recommendations for the same. It further estimates the respective embodied energies that could be saved by implementing recommendations.

To conclude, it emphasizes on the need in selecting appropriate material including size.

NEED OF OPTIMIZING ENERGY IN CONSTRUCTION PROJECTS

Pune is one of the fastest growing metropolise in India. Most of the construction projects in Pune adopt conventional construction practices of in-situ construction. These practices are most suitable to the stakeholders in the industry as workers are easily available. The stakeholders try to incorporate advanced technologoies like design mix, pre-cast RCC members in the construction process. But they do not ensure no-wastage of materials on account of certain reasons. Unskilled labor is being one of the common reasons.

Construction waste occupies considerable storage space either on the road, river beds, hill slopes and land fill sites. The major environmental impacts caused by these wastes dumps have an impact on surrounding landscape. Since construction projects are going-on in most parts of the city including re-development projects in old limits of PMC and new projects in peripheral areas, increased amount of construction waste dumped randomly is evident.

As many of the landfill sites are already being exploited, the disposal of construction waste is an issue that has been seeking attention within both the public and private sectors in Pune city. The increasing costs of disposal gets reflected in project costs, as contractors have to incorporate anticipated disposal costs in their bid costing. Based on above fact, the emphasis is given for initiatives to reduce waste during construction activities to save environment and energy.

ENERGY USE IN BUILDING -

The energy usage in building is at four stages

1. Pre-construction stage – Energy in pre-construction stage:
   - To extract & process the raw materials, manufacture the building material
   - To transport the raw material from origin to manufacturing unit
   - To transport finished material and components from manufacturing unit to construction site
2. During construction stage - Energy used during construction process:
   - To operate machinery on job-site
   - For movement of vehicles on job-site to carry out construction process
   - Human energy on job-site

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3. Post-construction stage - Energy used in collection, segregation and disposal of waste after construction process is over
   - Transporting waste material to designated location to reuse or recycle or landfill site for disposal
   - Energy used in reusing or recycling the waste
   - Energy used in process of material reuse
4. Operation of building - Energy in operation is the energy used once the building is occupied.

The focus of this paper is on energy used during construction stage and at post-construction stage. The energy used to dispose of waste material is also considerable in complete construction process. The energy in disposing waste can be minimized to greater extent by reusing or recycling the waste material.

CONSTRUCTION WASTE -

Construction waste is produced in large quantity by infrastructure projects, renovation or demolition of structures, etc. There can also be non-hazardous by-products generated. Waste is generated during site preparation, material use, material damage during handling, material non-use, excess procurement and human error.

Components of Construction waste debris typically include concrete, sand, aggregate, plastic, flooring material, rubber sealants, glass, metals and metal alloys, wood and wood based products, masonry material etc. Land clearing debris, such as weeds, rocks is also included in construction waste.

ENERGY OF CONSTRUCTION MATERIAL – EMBODIED ENERGY

The embodied energy of a product includes the energy used to manufacture it all through the process of mining or harvesting the raw material, refining, processing, and various stages of transport, to the finished product at the factory gate. The process of analyzing and quantifying the energy associated in these steps is part of Life Cycle Assessment of the building. The scope of this research is limited to the estimation of embodied energy involved in construction waste during construction process. The Life Cycle Assessment of that specific building material is out of the scope of this paper.

Energy consumption for the transport of manufactured products from factory to the site can have a large role in the total energy calculations. The energy consumption on the building site includes mechanical and human energy required for mixing, transporting, placing, finishing and cleaning, etc. The amount of energy used on the building site has increased considerably in recent years as a result of increased mechanization and increased labor cost.

MATERIAL LOSSES AND WASTAGE ON CONSTRUCTION SITE

Every material has “loss factor”, which describes how much of a particular material is typically lost during storage, transport and installation of final product.

The estimated material waste percentage differs as per construction material. The total amount of material purchased on the project site is as per this ´estimated quantity.

Table 1: Estimated wastage of construction material [v]

Sr. No.	Type of material	Estimated wastage
1	Cement	2 %
2	Sand	10 %
3	Aggregate	5 %
4	Concrete structural	2 %
5	Concrete binding (lean)	10 %
6	Reinforcement steel bars	3 %
7	Reinforcement steel mesh	10 %
8	PVC sheeting	15 %
9	Steel for windows	7 %
10	Timbering in trenches	5 %
11	Stone masonry	5 %
12	Marble lining	20 %
13	Wood for door frames	5-7.5 %
14	Wood for shutters	10 %
15	Wood for flooring / walling	5-10 %
16	Sheet roofing	2.1-2 %
17	Tile roofing	5 %
18	Floor railing	2-5 %
19	Wall tiling	3 %
20	Pigments (colors other than natural grey)	5 %
21	Paints	5 %

CASE STUDY OF PUNE - CONSTRUCTION WASTE GENERATED AT DIFFERENT STAGES OF CONSTRUCTION PROCESS

A residential project is studied to quantify the waste material generated on site. The study involves the quantification of waste in terms of embodied energy of material waste as well as in monetary terms.

Project details

- Project type – Residential project
- Location – Kondhwa, Pune
- Plot area – 22300 Sq. M.
- Built -up area – 12542.00 Sq. M.
- Number of buildings – 4 Numbers
- Number of Floors per building – Parking + 11 floors
- Ground coverage 4 buildings – 1688.43 Sq m (522.45 Sq m – 01 Tower
  388.66 Sq m – 03 Towers)

Refer table 4 for details of construction material purchased, material used for construction of buildings and quantity of waste generated during the construction process of the case study. The maximum wastage of material that is observed is of sand i.e. 24.50%. Tiles have about 16.67% wastage, where as masonry, steel and aggregate has 11.82%, 8.62% and 10.81% respectively. The least wastage is observed of PVC conduits i.e. 7.70%.

This study deals with wastage of concrete and mortar material (residue) and not the raw material (cement, sand and aggregate) separately. However handling losses of waste materials are not considered.

It is observed that there is a difference in percentage of waste material from literature review vis-à-vis to the one on site (case study). In such case the percentage from literature review is considerd as reference (base line).

Along with this, the material cost is also calculated. For this the current market rate is studied from Pune city. The calculation shows that, the cost of construction waste is 11.60% as compare to the total amount of material purchased. This increases the project cost and so as selling cost of residential unit. Refer table - 5 for detail calculations.

The use of embodied energy involved in construction waste is calculated and analyzed. The wastage of steel, concrete, cement and conduits is very less as compare to sand and aggregate, but the embodied energy involved in this wastage is very high. Also the embodied energy involved in tile and masonry wastage is also considerable. Refer table - 6.

RESULT

The calculation for case study shows that, the amount of construction waste generated on construction site is @17.50% with respect to the total material purchased on site for the project. It involves @11.60% of the purchased material cost. Also the embodied energy of construction waste is @10.70 % of the purchased building material on project site.

The material waste generation in conventional construction process is huge in monetary as well in environmental impact terms. Thus, cost saving potential and the reduction in environmental impact due to construction waste should be taken into consideration by adopting suitable measures for construction waste reuse and recycle.

STRATEGY

The reduction of construction waste generation is possible by preparing Waste Management Plan and implementing it during and after construction process. Following are some of the recommended practices and procedures for reuse of construction waste that can be adopted in Indian scenario.

RECOMMENDED PRACTICES AND PROCEDURE FOR REUSE

- The specification and quality of construction material plays important role in waste generation during the construction process. It also affects the quantity of material consumed in the construction and finishing of building.
- To control the material usage in the construction process, the coordination among all those involved in the design and construction process from site selection to project completion is necessary. They should meet on regular basis and address the issues like dewatering operation from site clearing process and excavation for foundation, material delivery, its storage and use, solid waste management, vehicle and equipment management. Also, contractor and labor training should be directed in the complete construction process of the project.
- The quality work affects lot in quantity of material usage and the waste generated in the construction process. Ex. The leveled surface of concrete slab to avoid use of screed material for tiling, masonry work in plumb to avoid excess

plastering material.

- The formwork used in the concreting work affects the material wastage in construction process. The appropriate selection of formwork material i.e. instead of wooden formwork use of steel formwork, cause less wastage of concrete. The smooth finish of using steel formwork reduces the quantity of plastering mortar and finishes the surface.
- Waste from one activity can be used as raw material for another activity. Site management with parallel activities need to organize to reuse and so as to reduce the waste
- Mandatory segregation of waste material / debris on site to reduce mixed construction material waste
- Material storage
  - i. Construct temporary material yard for separate storage of different materials. This reduces the mixing of materials stored on construction site.
  - ii. Store the material on water tight raised platform. This will save material at lower level from mixing in soil to avoid land contamination
  - iii. Cement bags stored directly on floor are vulnerable to contact with waster and moisture which leads to wastage of material to greater extent

Table 2: Recommended practices for reuse of construction material waste

S.N.	Waste material	Recommended practices for reuse of waste material on site
I	Block	To use as curbs to stop water runoff from garden area
		To construct pots for shrubs in terrace garden
ii	Tiles	To use tile adhesives for fixing tiles on leveled concrete slab, which avoids screed material use
		OR To use crush sand as bedding material for tiles
		To create Mosaic pattern in front of entrance door.
		To create pathways and walkway in the landscape area by using large and small pieces
		To create colorful fences around the flower beds
		To create reflective façade and terraces
iii	Concrete	To reuse concrete waste for temporary work or low-grade concrete work. This need parallel activities to plan on site.
		To recycle and use crushed concrete as aggregate for concrete
		To prepare lean concrete for PCC of compound wall, plinth filing, traffic movement
		To manufacturing paving blocks for lighter traffic movement
iv	Plastic	To recycle for re-manufacturing
v	Mortar	To use admixtures or plasticizers in mortar to reduce re-bounce waste
		To collect mortar at the end of day and pour in water to reuse it by crushing and adding cement for lower grade work of next day
		To collect mortar at the end of the day and mix in sand in proportion of 1:4. Use it for next construction work
vi	Packaging material	To collect and segregate the material at job-site. Send it for recycling. Do not store in contact with of water and moisture as it spoil the material
vii	Soil	To manufacture Stabilized mud blocks to be used in some other projects
		To use clay blocks for fencing around the trees or shrubs in landscape area of the project or in the terrace gardens
		Preserve top soil and do not mix with other construction waste. After the construction process is over, it can be used for landscape purpose on same or other site
viii	Brick	To use for paving in landscape
		To use as plinth filling material
		To construct curbs in landscape area to protect top soil run-off
		To construct Brick bat-coba for terraces and toilets
		To construct raised platform within building or project landscape area as a filling material
ix	Water	Save water by using gunny bag / cork bags for curing of concrete work
		Use curing compounds in concrete work
		Reduce water use by fixing water meter / water controller at pouring point into concrete mixer. This helps to maintain the quality of concrete.
		Collect cement mixed waste water through properly sloped trenches in sedimentation tank and reuse for construction work
x	Steel	To reuse 20mm diameter and above small length bars after coupler binding
		To send for recycle as it is recycled 100%
		To use sheering machine for steel cutting. This helps to reduce steel waste
xi	Paint	To use good quality paint to reduce consumption by quantity at source (minimum coats give perfect shade)
		To appoint skilled labor to use paint properly and reduce waste
		Good quality of plastering reduces the excess consumption of paint
xii	Rock from Excavation	To break with the help of crusher
		To use large size stone for construction of compound wall
		To reuse small size stones as aggregate
		PCC from crushed stone to reduce source material consumption

ESTIMATED QUANTITY OF REUSED MATERIAL AND EMBODIED ENERGY

The construction waste can be reused for various site development activities in the same project. The quantity of construction waste that can be reused for different construction stages is calculated and the embodied energy involved in reused waste material is calculated. Refer to table 4 and table 5. The cost of construction waste against the total material purchased for project is 11.60%. This is large investment in construction waste. See table 6 for detail calculations.

Refer to table - 7 for the detail calculations of quantity of construction waste reused on same site for other construction activities. The masonry material reuse is up to 80.57% in brick bat coba filling for terrace and dry terrace of the residential units and the filling below deck area.

The quantity of concrete material waste can be reused up to 93.00% in lower grade concrete for paving blocks of open parking, plinth filling of club house and bedding material below walkway in open space.

The waste steel bars of diameter 8mm, 10mm, 12mm can be used for chair bars, pins in beam. Also steel bars of length 4’0” to 6’0” can be used for toilet slab and consecutive footings. This can consume up to 10% of steel waste quantity.

The segregated and preserved mortar waste can be reused for paver block bedding material. This consumes 13.12% of the mortar waste quantity.

The tile waste can be reused up to 13.12% in parapet top, Flooring of staircase landing at terrace level, Mosaic flooring design in front of entrance door of residential units.

These findings reveal that, up to 23.25% of total construction waste can be reused on same project. This help to save the quantity of virgin material required in the site development work for the same project. The remaining waste material can be reused on the other project site as per requirement of the work.

ESTIMATED QUANTITY OF RECYCLED MATERIAL AND EMBODIED ENERGY

The construction waste material can be recycled at job-site. The estimated quantity of construction waste that can be recycled is identified and the embodied energy involved in it is calculated. This helps to save the energy required in the manufacturing process of virgin material.

Refer table - 8 for the detail calculations of quantity of construction waste recycled on job-site. The steel waste that remains after reusing on site can be sent for recycling. Since steel can be 100% recycled, it can be sent to manufacturing plant.

The PVC conduit waste that generates from plumbing and electrical waste should be collect and segregated carefully and sent to the job-site. This can help to recycle 85% of PVC conduits for manufacturing of new product.

WASTE MATERIALS AND 3R -

Today the construction industry is facing the issue of Management of huge construction waste. This research recommends the ways to reduce, reuse and recycle of construction waste in Indian context. Besides a clear understanding of the general concept of waste, it is helpful to use a classification of waste in different categories, in order to understand the wide range of possible corrective actions related to its prevention.[vi]

The different construction waste generated on site can be reduced, reused and recycled. Following are the possible measures towards waste minimization by implementing 3R concept to different waste materials on construction site.

Table 3: Construction waste and 3R

Sr N	Construction waste	Reduce	Reuse	Recycle
1	Soil		✓	
2	Cement	✓		

3	Sand	✓	✓	
4	Aggregate	✓	✓	
5	Concrete	✓	✓	✓
6	Steel	✓	✓	✓
7	Masonry	✓	✓	✓
8	Wood	✓	✓	
9	Tiles	✓	✓	
10	Pipes	✓		✓
11	Aluminum	✓	✓	✓
12	Glass	✓		✓
13	Plastic		✓	✓
	Packaging material			
14	• Paint cans	✓	✓	✓
	• Cardboard boxes	✓	✓	✓

Most construction waste materials can be reused and recycled. Often, it is just a matter of separating waste, either on-site or off-site and sending it to the relevant waste stream.

Dedicated storage spaces should be allocated for the collection and sorting of waste. These spaces should be easily accessible to workforce and be in close proximity to waste collection points. Bins or storage containers should be allocated to accommodate different waste streams including reusable waste, recyclable waste, rubbish (non-recyclable waste). It is important that storage areas are conveniently located within a construction site.

Also, the initiative and training to labor is as important aspect. The labor should be aware of the signage/graphics on the waste-bins and contribute in sending the waste to relevant material waste-bins.

CONCLUSION –

In the construction industry, the materials are transformed into elements; elements are transformed into components, components into systems and building. Thus they define the flow of materials and energy during construction and are responsible for flows of materials and energy from building sites.

The construction waste is generated from the stage of site preparation to building services like plumbing, electrification of the construction process. The various waste materials like concrete, mortar, tiles, brick, packaging material, water are generated from these stages.

The embodied energy involved in construction waste can be reused up to 35.23% and recycled up to 26.74% with the recommended practices and procedures in this research paper. An important procedure like placement of different containers to collect and store the segregated wastes should be adopted on site. The maximum reuse of waste material will minimize the resource consumption for the construction material manufacturing. This will also save the cost invested in construction material.

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References:

[i] www.empulseglobal.com, Services, Market research, Book-A market research in India, Chapter 7: Indian Research for Industry Verticals, Real_Estate_&_Construction_Market_Research_in_India

[ii] Jain Manasi, October 2012, Economic Aspects of Construction Waste Materials in terms of cost savings – A case of Indian construction Industry, International Journal of Scientific and Research Publications, Volume 2, Issue 10, ISSN 2250-3153

[iii] Engineering Issue, March 2013, Sustainable Materials Management in Site Cleanup, EPA, Office of Solid Waste and Emergency Response (5203P) EPA 542-F-13-001,

[iv] Information, 2001, International council for research and innovation in building and construction : construction site waste management and minimization, pp 5

[v] Chitkara K.K., Construction project management - Planning, scheduling and controlling, Page no. 330-331

[vi] A study of various propositions to manage c&d waste in construction: a value engineering perspective, Volume2, Issue5 (May-2012), ISSN: 2249- 9482, IJESS

Bibliography:

Anagal Vaishali et. Al. , Oct. 2012, Construction and demolition waste management with reference to case study of pune, Twenty-eighth National Convention of Civil Engineers & National Seminar on "Role of Infrastructure for Sustainable Development", Institute of Engineers, India, Roorkee.

Sote- Wankhade Dharati, April 2013, "Optimization of material to manage construction waste", M. Arch. Environmental Architecture, Thesis, Dr. B. N. College of Architecture, Pune

Bhonde Dinesh, Published 16 papers on Engineering, Education, Examination and finance management, in national and international journals and conferences

Junli Yang and David Mitchell, 2010, Approaches to Waste Materials Management in Construction Projects, The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors

Mogodi Keabetswe, Mosomane Rosinah and Mukucha Claver, 2009, An investigation into the waste management programmes of selected construction sites in Johannesburg, The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors

Ajayi O. M., Koleoso H. A., Soyingbe A. A., Oladiran O. J, 2008, The practice of waste management in construction sites in Lagos state; Nigeria, The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors

Lau H.H., Whyte, A., and Law P.L., Summer 2008, Composition and Characteristics of Construction Waste generated by Residential Housing Project, Department of Civil & Construction Engineering, Curtin University of Technology (Sarawak Campus), Sarawak, Malaysia AND 2Department of Civil Engineering, University Malaysia Sarawak, Malaysia

Pilar Mercader Moyano M., Antonio Ramírez de Arellano Agudo and Manuel Olivares Santiago, 2011, 5, Calculation Methodology to Quantify and Classify Construction Waste**,** The Open Construction and Building Technology Journal, (Suppl 2-M3) pp 131-140

Kentucky, 2005**,** Best Management Practices for Construction Activities, Environmental and Public Protection Cabinet, Division of Conservation And Division of Water

Muhwezi L., Chamuriho L. M. and Lema N. M., April 2012, An investigation into Materials Wastes on Building construction Projects in Kampala-Uganda, Scholarly Journal of Engineering Research Vol. 1(1), pp. 11-18

Bissink B. A. G. and Brouwers A. J. H., March 1996, Construction waste – Quantification and source evaluation, Journal of construction engineering and management, pp 55

Bjorn Berge, The ecology of building materials, Second edition, translated by Chris Butters and Filip Henley

Yadav* S R, National Institute of Construction, Management and Research (NICMAR), India,

Pathak S R, August 2009, College of Engineering Pune (COEP), Pune, India, Use of recycled concrete aggregate in making concrete- an overview, 34th Conference on OUR WORLD IN CONCRETE & STRUCTURES: 16 – 18 August 2009, Singapore

Rai manasi, Ghawate Pratik, August 2013, Current infrastructure scenario and rise in construction and allied industries in India, ISSN: 2278 – 7798 International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 8, August

Articles.timesofindia.indiatimes.com/2012-07-09/ Pune, Jul 9, 2012, City's concrete spread must be on eco-friendly lines: Centre for Science and Environment, Radheshyam Jadhav, TNN 04.36AM IST

Best management practices manual for construction sites in Honolulu, prepared by Department of Environmental services city and county of Honolulu in cooperation with The general contractors association of Hawaii, May 1999

Construction Waste Management Guide, for Architects, Designers, Developers, Facility Managers, Owners, Property Managers & Specification Writers, Resource venture, Third edition, September 2005

Waste minimisation in construction, Reducing material wastage in Construction, Guidance for clients, contractors and sub contractors on how to deliver good practice in materials procurement and usage. WRAP, Material change for better environment

www.business-standard.com/india/news/Pune, June 21, 2006 builders assesses waste management, Our regional bureau/ Mumbai/ Pune,

https://www.victoria.ac.nz/architecture/centres/cbpr/.../ee-coefficients.pdf visited 26th May 2014
http://www.boral.com.au/images/common/clay_bricks_pavers/pdfs/brick_legend.pdf visited 26th May 2014
http://media.cannondesign.com/uploads/files/MaterialLife-9-6.pdf, Material Life, Embodied energy of building material, Cannondesign

Table 4 - Construction waste of Case study – Residential project at Kondhwa, Pune

Sr. No	Waste material	Specification of material	Unit	Material purchased	Material used	Material Waste	% of Waste
1	Concrete with Portland cement	Structure, reinforced	Cu m	4526	4305	221	5
2	Mortar and plaster		Sq m	71446	64461	6985	10
			Cu m			126	
			Cu m		Total	347	
3	Crush Sand		Kg	6451200	4856090	1595110	25
			Cu m	3863		955	
4	River sand		Kg	4817400	3649147	1168253	24
			Cu m	3108		754	
5	Aggregate	Gravel	Kg	5665250	5052930	612320	11
			Cu m	3907		422	
6	Cement	Portland cement	Kg	2436450	2265040	171410	7
			Cu m	1624		114	
			Cu m		Total	2245	
		Net loss of Sand, Aggregate and Cement due to handling, storage and transportation				1899	
7	Steel	Galvanized from ore	Kg	570370	521200	49170	9
8	Masonry	Aerated concrete					
		Fired clay (well fired bricks massive) size 150 x 150 x 75	No	769340	678400	90940	12
9	Tiles	Ceramic tiles (9-21 kg/sq.m.)	Sq m	16800	14000	2800	17
10	Electrical conduit	Polyvinyl Chloride Pipe (dia 40 to 63 mm, wt 0.33 to 0.56 kg/m)	R m	45000	42000	3000	7
11	Plumbing conduit	Polyvinyl Chloride Pipe (dia 40 to 110 mm, wt 0.33 to 1.64 kg/m)	R m	23000	21000	2000	9

Table 5 - Cost effect due to construction waste

Sr. No	Waste material	Specification of material	Unit	Material purchased	Material used	Material Waste	Rate of material		Total Amount of purchased material	Total amount in waste material
							Unit	Rs per unit		Rs
1	Concrete with Portland cement	Structure, reinforced	Cu m	4526	4305	221				
2	Mortar and plaster		Sq m	71446	64461	6985				
			Cu m			126				
			Cu m		Total	347				
3	Crush Sand		Kg	6451200	4856090	1595110				
			Cu m	3863		955	Cu m	1100	4249293	1050671
4	River sand		Kg	4817400	3649147	1168253				
			Cu m	3108		754	Cu m	1950	6060600	1469738
5	Aggregate	Gravel	Kg	5665250	5052930	612320				
			Cu m	3907		422	Cu m	1050	4102422	443404
6	Cement	Portland cement	Kg	2436450	2265040	171410	Bag	320		
							Kg	6.40	15593280	1097024
7	Steel	Galvanized from ore	Kg	570370	521200	49170	Kg	48	27377760	2360160
8	Masonry	Aerated concrete								
		Fired clay (well fired bricks massive) 150 x 150 x 75	No	769340	678400	90940	Piece	4.50	3462030	409230
9	Tiles	Ceramic tiles (9-21 kg/sq.m.)	Sq m	16800	14000	2800	Sq m	400	6720000	1120000
10	Electrical conduit	Polyvinyl Chloride Pipe (dia 40 to 63 mm, wt 0.33 to 0.56 kg/m)	R m	45000	42000	3000	R m	20	900000	60000
11	Plumbing conduit	Polyvinyl Chloride Pipe (dia 40 to 110 mm, wt 0.33 to 1.64 kg/m)	R m	23000	21000	2000	R m	100	2300000	200000
									7,07,65,386	**82,10,227**
										12%

Table 6 – Embodied energy in construction waste

Sr. No	Waste material	Specification of material	Unit	Material Waste	Density of material (Weight per volume)	Conversion factor	Total Quantity	Embodied energy of material	Total Embodied energy in Waste

					Kg/m³		Kg	MJ/Kg	MJ
1	Concrete with Portland cement	Structure, reinforced	Cu m	221	2400		530400	1.50	795600
2	Mortar and plaster		Sq m	6985	1900	126 Cu m	238887	1.00	238887
									1034487
3	Crush Sand		Kg	1595110	1670		1595110	0.50	797555
4	River sand		Kg	1168253	1550		1168253	0.50	584127
5	Aggregate	Gravel	Kg	612320	1450		612320	0.50	306160
6	Cement	Portland cement	Kg	171410	1281 - 1500		171410	3.6 - 4.0 (3.8)	651358
									2339200
		Net loss of embodied energy of Sand, Aggregate and Cement due to handling, storage and transportation							1304713
7	Steel	Galvanised from ore	Kg	49170	7500		49170	25	1229250
8	Masonry	Fired clay (well fired bricks massive) 150 x 150 x 75	No	90940		2.5 Kg per piece	227350	3	682050
9	Tiles	Ceramic tiles (9-21 kg/sq.m.)	Sq m	2800	2000	12 kg / Sq m	33600	8	268800
10	Electrical conduit	Polyvinyl Chloride Pipe (dia 40 to 63 mm, wt 0.33 to 0.56 kg/m)	R m	3000		0.42 Kg / R m	1260	85	107100
11	Plumbing conduit	Polyvinyl Chloride Pipe (dia 40 to 110 mm, wt 0.33 to 1.64 kg/m)	R m	2000		0.78 Kg / R m	1560	85	132600

Table 7 – Estimated quantity of reused construction waste

Sr. no.	Waste material	Reuse practice	Unit	Total Waste	Unit	Total reused waste in 4 buildings – each building parking + 11 floors	Unit	Estimated quantity of waste material reused	Estimated energy involved in reused material in MJ
1	Tiles	Flooring of staircase landing at terrace level			Sq m	117	Sq m	117	
		Mosaic flooring design in front of entrance door of residential units			No.s	176	Sq m / design	2	Sq m	352	
		Top finish for sit out in the open space and entrance lobby			M		No.s	20	Sq m	15	
		Parapet top			M	603	Thicknes s	0.15	Sq m	90	
			Sq m	2800		Total			Sq m	574	55140
						Percentage				21	
2	Concrete	Use for lower grade concrete below open parking paving blocks			Sq m	470	M	0.30	Cu m	141	
		Plinth filling of club house			Sq m	84	M	0.45	Cu m	38	
		Bedding material below walkway in open space			Sq m	180	M	0.15	Cu m	27	
			Cu m	221		Total			Cu m	206	739978
						Percentage				93	
3	Steel	Steel bar 8mm, 10mm, 12mm for chairs, pins in beam (0.5%)						5% of total waste	Kg	2459	
		Steel bars length 4'0" to 6'0" for toilet slab, footing (0.5%)						5% of total waste	Kg	2459	
			Kg	49170		Total			Kg	4918	122925
						Percentage				10	

4	Mortar (Plaster)	Paver block bedding material (Parking and club house)			Sq m	6109			6109	
			Sq m	6985		Total		Sq m	6109	208942
						Percentage			88	
6	Brick	Coba filling / water proofing to terrace of residential unit (3 towers)			Sq m	110	11	Sq m	1214	
		Dry terrace			Sq m	35	11	Sq m	386	
		Water proofing for terrace slab			Sq m	1688				
		Filling below deck area						Sq m	435	
			Pieces	90940		Total			2035	
						36 Pieces / Sq m			73274	549558
						Percentage			81	
						Total embodied energy in Reused waste material				1676620
									Percentage	35

2	Electrical conduit	Polyvinyl Chloride Pipe (dia 40 to 63 mm, wt 0.33 to 0.56 kg/m)	R m	3000	2850	Kg/R m	0.42	Kg	1197	101745
							Percentage		95%	
3	Plumbing conduit	Polyvinyl Chloride Pipe (dia 40 to 110 mm, wt 0.33 to 1.64 kg/m)	R m	2000	1900	Kg/R m	0.78	Kg	1482	125970
							Percentage		95%	
									Total embodied energy in Recycled waste material	1272503
									Percentage	27%

Table 8 – Estimated quantity of recycled construction waste

Sr. No	Waste material	Specification of material	Unit	Construction Waste	Waste in recycle		**Estimated quantity of waste material reused**	**Estimated energy involved in recycled material in MJ**
1	Steel	Galvanised from ore	Kg	49170	41792	Kg	41792	1044788
					Percentage		85%	