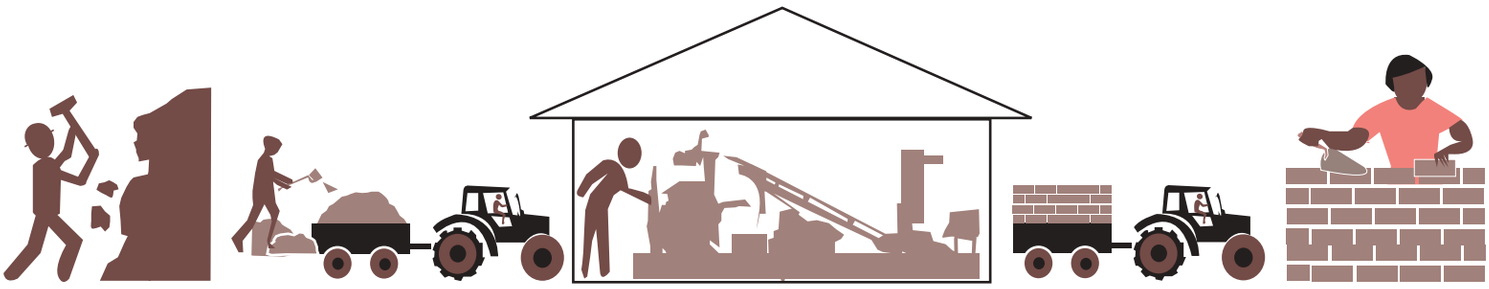
# RESOURCE EFFICIENCY IN CONSTRUCTION SECTOR

## Market Analysis of Utilisation of Secondary Raw Materials for Manufacture of Building Materials in Bangalore City

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Development Alternatives

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## Imprint

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Resource Efficiency and Sustainable Management of Secondary Raw Materials

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## Executive Summary

Construction industry is growing rapidly in India and so is the generation of Construction and Demolition waste. Bangalore being one of India's fastest growing cities generates huge quantities of C&D waste. The market analysis assesses that around 700 TPD of C&D waste is generated in Bangalore. The waste is presently been ordered to be filled into 10 authorized landfills around the city, which are designated by the Urban Local Bodies.

The present study on market analysis gives an overview of the actual management system of C&D waste in Bangalore and relates it to the raw material requirement for the construction sector in Bangalore. The study also explores the possibility of utilizing C&D waste as a resource rather than waste and converting it into a secondary raw material like coarse and fine aggregates to be used in construction Industry.

The study also includes developing the business opportunities of processing C&D waste into aggregates and utilizing it for manufacture of paver blocks which is a construction material for laying pavements and several new business cases have been defined in the report. It was observed that processing C&D waste into raw material (aggregates) and making paver blocks out from C&D raw material industry results in cost saving of upto estimated 14% and 12% for the entrepreneurs while compared to utilisation of virgin aggregates (stone from quarries).

Based on the survey results and the analysis conducted on the business cases, recommendations for different stakeholders for mainstreaming use of C&D waste in construction sector are duly included in the study. Some of the key highlight findings of the study are mentioned below:

## Key Points

- Construction and Demolition waste is dumped in 3 sites out of the 8 designated ones.
- Costs of virgin aggregates increase rapidly with distance of stone quarries from the building material manufacturers.
- Opportunity exists for processing of C&D waste into aggregates through decentralised models if there is a viable business case for mobile crushing units or stand-alone C&D waste processing facilities of different scale capacities.
- There is no shortage of raw material, but acceptability of recycled aggregates was found amongst the paver blocks manufacturers if uninterrupted supply is guaranteed at lower rates than that of virgin aggregates.
- Business case analysis suggests that cost savings up to 20% from processing of C&D waste can be observed as compared to natural aggregate.
- Cost savings up to 5% can be observed for finished products such as paving blocks made from recycled aggregates.
- Lack of awareness about C&D waste aggregates and products amongst building material manufacturers exist which needs to be tackled through proper policy intervention and awareness drives.

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## Abbreviations

| | | |
|---|---|---|
| **C&D waste** | – | Construction &Demolition waste |
| **BBMP** | – | BRUHAT BENGALURU MAHANAGARA PALIKE |
| **TPD** | – | Tons Per Day |
| **C.P** | – | Cost Price |
| **S.P** | – | Selling Price |
| **ULB** | – | Urban Local Body |
| **PPP** | – | Public Private Partnership |

## Introduction

Bangalore, also known as the 'Silicon Valley of India' or the 'Knowledge Capital of India', is the capital city of the State of Karnataka. The city is one of the most sought after 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 boom in the IT sector has had an impact on the development and urbanisation of Bangalore. The city is governed by Bruhat Bangalore Mahanakara Palike (BBMP). It is one of the largest Municipal Corporations in India, consisting of 198 wards.

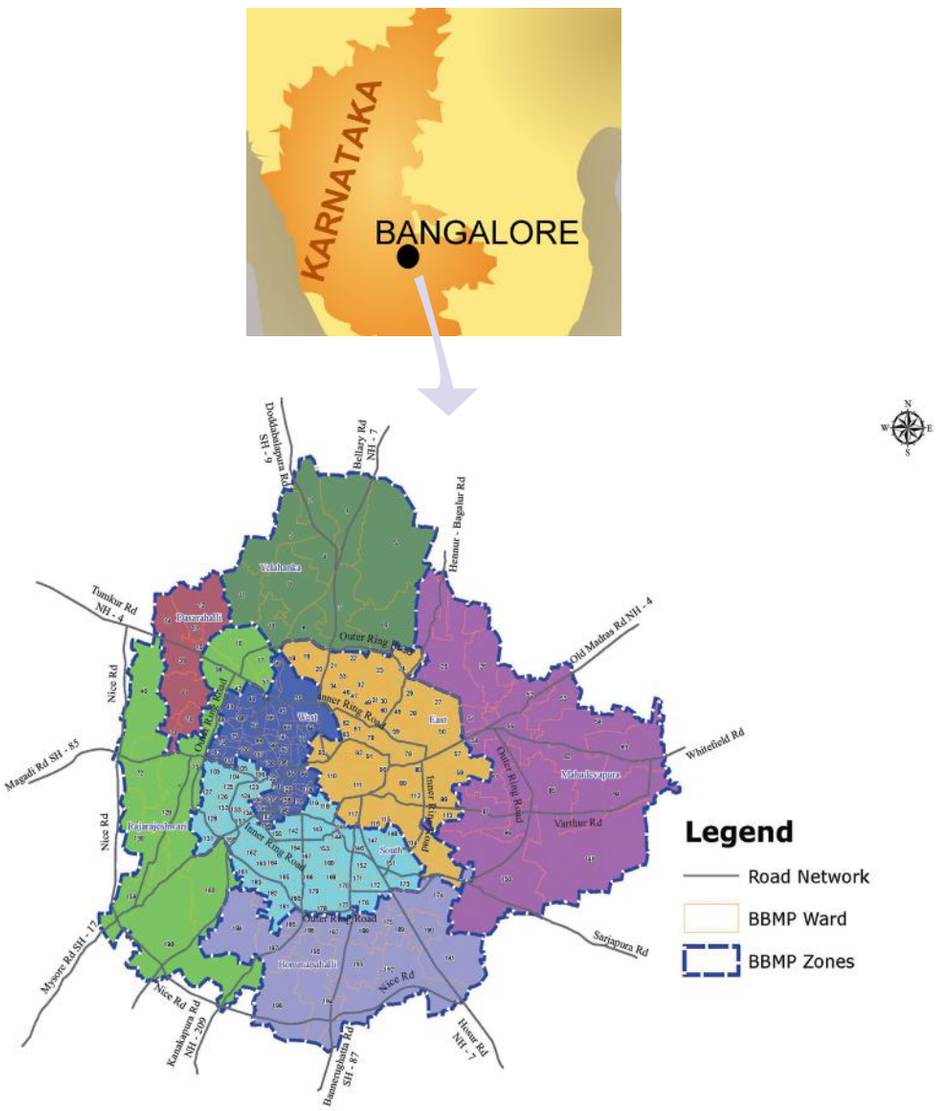



Figure 1: Map of Bangalore

Table 1: Demographics at a glance

| | |
|---|---|
| Area (BBMC) | 2190 sq. km |
| Population (BBMC) | 10 Million |
| No. of Wards/Zones | 198/5 |
| Area (BMRDA) | 4500 sq. km |

## Objective of Study

“Fostering Resource Efficiency and Sustainable Management of Secondary Raw Materials in India” is a project being implemented to achieve an improved understanding of resource challenges and resource efficiency with focus on Construction and Demolition (C&D) waste and its potential for reuse as a secondary material in the construction sector in India. As a part of the project, Development Alternatives (DA) along with GIZ conducted a market study in the city of Bangalore to understand the C&D waste ecosystem and evaluate various stakeholders’ interests towards the use of C&D waste processing for end products. Surveys and interviews were conducted involving various stakeholders in the C&D supply chain to collect data on the existing waste deposition sites, location of various stone quarries, building material manufacturers and C&D processing units.

The overall objective of the study includes primary evaluation of the Construction and Demolition (C&D) waste management scenario in Bangalore, understanding the construction material market in Bangalore and then proposing suitable strategies to enhance the processing and utilisation of C&D waste.

## Methodology Adopted

The methodology was divided into design, data collection, analysis and interpolation.

### Design

Initially the stakeholders from whom the relevant information could be gathered was identified. A list of contact persons were identified under each category and people (maximum of 5 per category) shortlisted, based on initial conversations, stakeholder interest and geographical spread in city.

A data collection questionnaire was developed for data collection in the field for different stakeholders.

### Data Collection

This phase forms the heart of the study, where all the data and information were collected. Data collection was based on secondary literature and field assessments.

Secondary literature including information on size, population, geography and online articles on construction sector in Bangalore were used to have a general understanding of the city.

Later field visits were conducted to gather information from stakeholders based on the questionnaire prepared. Data was collected from various geographies of Bangalore to have an understanding on the overall industry all over the big city.

Even though different stakeholders were met, the study was focused on entrepreneurs in different geographies of Bangalore city who are already involved in manufacture of building materials using raw materials like aggregates and sand.

### Analysis and Interpolation

Collected data was used to analyse the existing Construction Material Market in Bangalore to predict a market for secondary building materials in comparison/competition to the existing market.

## Observations and Assessment of field data

### Construction and Urbanisation Trends

Bangalore is a city that is rapidly developing due to the boom in IT sector. Majority of construction happened in the last three decades. Huge greenfield and brownfield projects are observed all around Bengaluru especially in the south and the east extension where high raised buildings are being majorly constructed in association with the IT industry. In the north and south, more of villa projects and plot development projects take place which is much less resource consuming. Even though the central region is heavily urbanised and already constructed to the brink, substantial construction and demolition activities are occurring within the city in areas like Mahadevapura, Bohmanahalli, Rajarajeshwari etc. However, increasing activities can be seen in different nodal regions of the city.

The last decade has also seen a phenomenal change in the use of construction materials in Bangalore. The builders' preference has changed from red bricks to locally produced concrete bricks. Majority of construction activities have shifted to concrete bricks in the last five years. Red bricks are only used for aesthetic decoration 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 percent by use of concrete bricks since, lesser number of bricks need to be bound together and thinner layer of cement is required for plastering. The use of concrete bricks also leads to a marginal increase in carpet area compared to a red brick wall.

Construction materials like Paver blocks, kerb stones etc are also of huge demand in Bangalore. Huge number of manufacturers are settled inside and around all sides of the city due to the easy availability of material and good market of the products.

Paver block

Concrete block

## Market for Construction Materials

The growing construction industry also raises the demand for building material. Precast concrete construction materials including paver blocks, kerb stones, tiles etc are of huge demand. Owing to the comparatively less investment required and less space requirements for the enterprise, a huge number of enterprises of different scales of production have been established for the manufacture of these products in and all around Bangalore city.

The easy availability of raw materials from quarries in and around Bangalore also is an added advantage to the enterprises who use the quarry products for coarse aggregates (6mm, 10mm and 20mm aggregates) and also fine aggregates (instead of river sand).

Even though a huge number of building materials have a good market in Bangalore, the materials listed below are the ones which have maximum market and made by the manufacturers on a proactive approach.

### *Paver Blocks*

Paver blocks are of huge demand in Bangalore. They are used for laying pavements for walkways, car parks, garages, ports, petrol pumps etc. From field surveys it was studied that interlocking pavers are of maximum demand. Interlocking I-Shaped Pavers and Zig-Zag shaped pavers are the most seeked out models. Interlocking bricks of 60mm thickness is most preferred for pathways, car porches, Bus stands, Veranda decoration etc but 80mm pavers are more preferred for petrol pumps, Ports, Industrial areas etc where more load bearing capacity is required due to transport of Heavy duty vehicles. The paver blocks are most commonly of 20-25 grade materials.

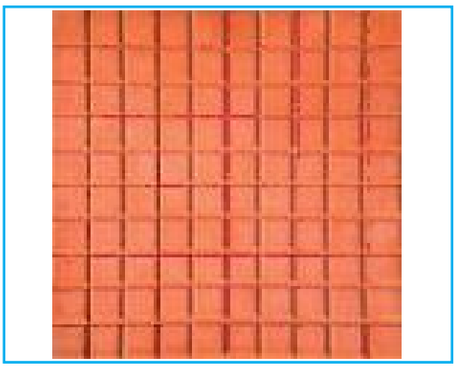
In addition to normal paver blocks there is a market for ISI marked paver blocks which are high grade materials (M40) and is usually preferred by huge private projects where quality and lifetime is given maximum preference.

### *Concrete Blocks*

Concrete Blocks are most commonly used instead of red clay bricks in Bangalore. Concrete bricks are used in construction of single storied temporary structures to high raised buildings. They are manufactured commonly in 3 different sizes of 4”, 6” and 8”. The latter two are used for outer walls whereas 4” bricks are used for cover walls inside a building.

The concrete bricks are cost effective since

One 6” Concrete block is equivalent to 8 standard size concrete bricks saving labor and binding material



Concrete tile

Kerb stone

Concrete brick walls require less thicker plastering hence reducing cost of construction and increase in carpet area

### *Kerb Stones*

Kerb are in demand due to the huge number of infrastructure projects happening in Bangalore. Kerb stones are used in construction of the outer ring of landscapes, foot pathers, road dividers etc and form a kerb along the side of a road.

450 mm and 600 mm long half battered Kerb stones are of maximum demand. The stones are of usually made of M20 grade material and in standard grey color which is painted according to the buyers needs onsite.

### Concrete tiles

Concrete tiles although is not as popular as paver blocks and concrete blocks, is still in very big demand for walkway carpeting, step carpeting, verandah decoration etc. The tiles are usually made in M15 and M20 grade material and most commonly in 1ft X 1ft dimensions.

All the above mentioned models are manufactured in a pro-active manner and stocked in yards whereas there are other materials which include precast water channels, Jallis, Coping stones etc that get manufactured on demand.

## Raw Material Availability and Manufacturing Process

The raw materials required for the manufacture of the listed construction materials are Aggregates (12mm and 6mm), M-sand and Cement. Unlike most of Indian cities, Bangalore does not have shortage in availability of aggregates. Bangalore is located on a granite rock strata and stone quarries are located all around the city. The last reported case of resource shortage was more than 5 years ago and for a period of only 2 months.

M-sand is a by-product of Aggregates and is available at much cheaper rate than river sand. The material is also easily available from the quarries and hence the building material manufacture sector does not have resource shortage in Bangalore.

But the survey done among enterprises in Bangalore reveals that they are open to change. Acceptability of recycled aggregates was found amongst the paver blocks manufacturers if uninterrupted supply is guaranteed at lower rates than that of virgin aggregates.

Table 2: Cost of construction raw materials

| Material | Cost |
|---|---|
| Aggregates (12mm and 6mm) | 20-25 Rs/CFT |
| Stone Dust (M-Dust) | 25-30 Rs/CFT |
| Cement (53 grade) | 350-400 Rs/ 50 kg |

## Overview of C&D waste management in Bangalore

Demolition activities account for majority of the C&D waste generated in Bangalore. Analysis of the demolition industry reveals that the average age of demolished buildings range widely from 15 to 40 years. Buildings constructed in the last 15 years are also renovated or demolished to create workspace for commerce and industries. Buildings more than 25 years old are found to be single or double storied structures whereas those of 15-25 year old are multi-storeyed or high rise buildings with a concrete frame structure.

Like many other Indian cities, the C&D waste generated and disposed in BBMC area are not monitored and hence a data gap exist in the quantification of C&D waste. But as per the market analysis conducted by Development Alternatives, it is estimated that around 0.2 million metric ton of C&D waste is generated in BBMC area per annum, which is estimated to be around 25% of the total MSW collected and disposed in Bangalore.

The different stages of management of C&D waste from generation to disposal in Bangalore city can be classified into different processes as mentioned 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.

In case of government buildings, 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 the contractors for demolition.

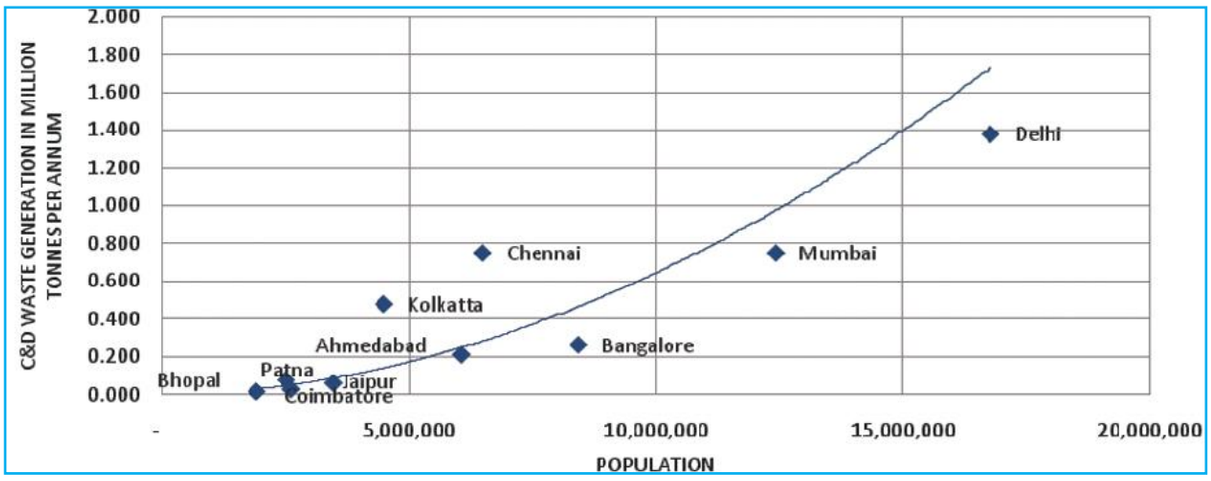



Figure 2: Correlation between C&D Waste generation and population in 10 different Indian Cities.

### 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 is 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 the informal sector. 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. The cost of different C&D waste valuables are detailed in Table 3.

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. The cost of different C&D waste valuables are detailed in Table 3.

Table 3: Cost of different C&D waste valuables

| Material | Selling Price |
|---|---|
| Whole Bricks | INR 1/ Brick |
| Metal | INR 10-12/kg |
| Demolition Debris | INR 2000/ Truck Load |
| Wood frames | INR 500-3000 |

### Transportation & Disposal

As per the guidelines set by BBMP, the demolition contractors are mandatorily required to dump the

C&D waste in used up granite quarries outside the city. BBMP has allotted 8 designated used up quarries around Bangalore city for the dumping of C&D waste, out of which 3 of them are currently active at Srinivasapura, Anjanpura and Mallasandra.

Transport contractors are assigned for moving the C&D waste from site to the dumping yard. The transport contractor either transport the waste to the quarries, use it for land-filling on some other construction site on demand of clients; and in some cases illegally dump it on any open space to minimise transportation cost.

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 5000/ tonne 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 civilians to dump their waste by bearing all the transportation cost.

### Processing of C&D waste

Processing of C&D waste is not a prevalent activity in Bangalore. Since the C&D waste is considered as a solution to cover the used up quarries and due to the lack of shortage of raw materials, the stakeholders consider C&D more as a filler material than a raw material.

Rock Crystals Pvt Ltd[1] is an enterprise that process the concrete part of C&D waste and convert it into aggregate raw material. The C&D waste from major construction and demolition projects are brought to Rock Crystals Pvt Ltd by the generator and the waste is being processed into aggregates of 6mm, 12mm, 20mm, 40mm, GSB (mixed aggregates for sub-base) & M-sand. The operator processes an average of 2500 tonnes per month of C&D waste from private builders and contractors. 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. Rock Crystals Pvt Ltd also pays the generator transport fees of 120 Rs/Ton for the material.

[1] Location marked as 'rock crushing unit' in Bangalore city map in this report

## Analysis of Market Study

The success story of Ahmedabad city attached as Annexure 3 reveals that C&D waste can be successfully be processed into coarse and fine aggregates that can be used for manufacture of construction materials including paver blocks, kerb stones and other non-structural materials.

As part of the market analysis, in order to find the market feasibility of processing of C&D waste into secondary raw materials, mapping of existing rock crushing industry cluster and the paver block manufacturing cluster was also undertaken.

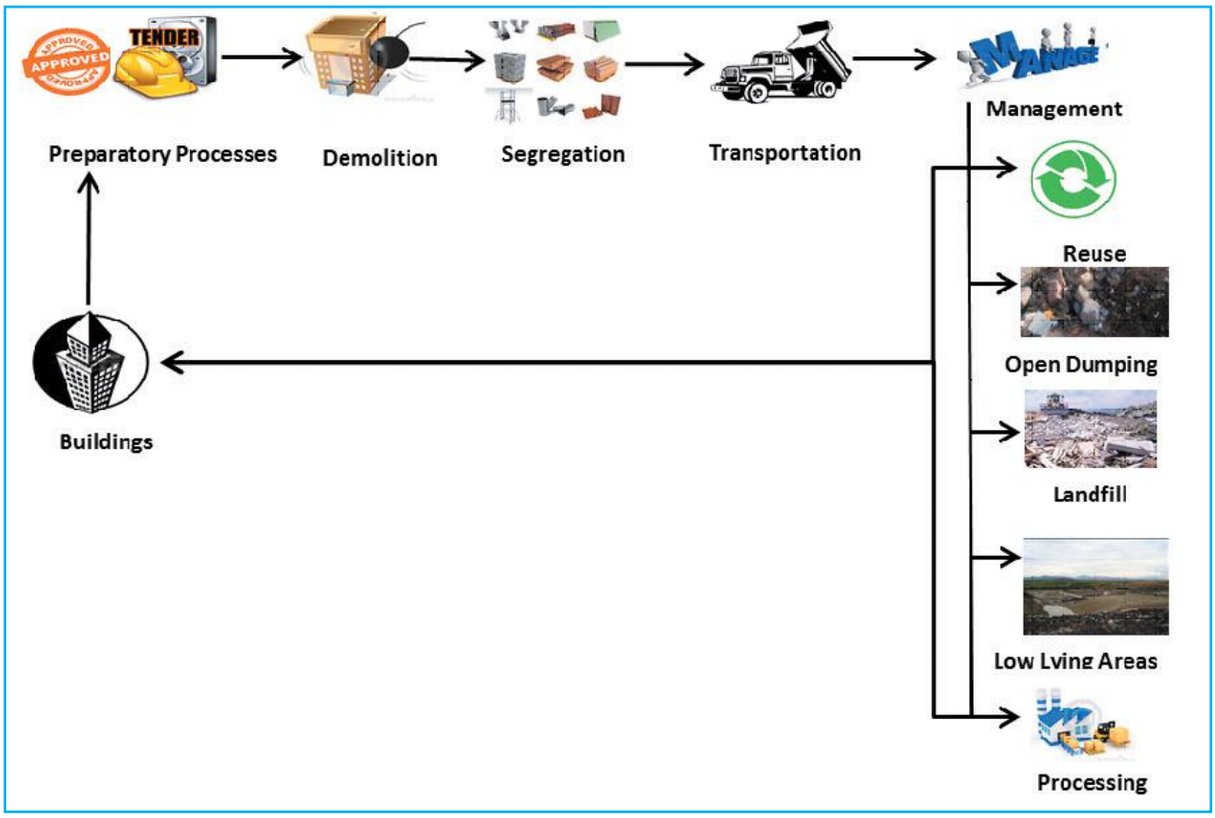
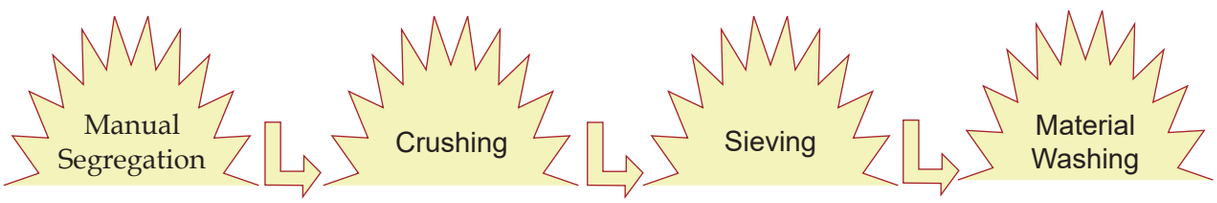



Figure 3: Process flow on C&D waste management in Bangalore

The analysis of results as shown in Submission 3 and Table 4 shows that the distance of the active stone crushing units is equivalent to the used up quarries in Bangalore. The analysis also prove that the distance of the existing processing unit to existing paver block manufacturing cluster is also less compared to the nearest stone quarry cluster. This opens up the opportunity to utilize processed C&D waste as a source of raw material for enterprises in Bangalore at a lower cost and also shows the need for decentralized processing of C&D waste in Bangalore city.

For example, distance of the C&D waste dumping area from the Yelhanka cluster of paver block manufacturers is lesser than the distance to the nearest stone quarry cluster (Table 4).



Dumping of C&D Waste in Quarry (Kannuru village)

Table 4: Distance to the nearest stone quary cluster

| Average distances (kms) | | | |
|---|---|---|---|
| **Paver Block Manufacturing Cluster** | **Nearest Stone Quarry cluster** | **Nearest Dumping site** | **Rock Crystals Pvt Ltd** |
| Kannuru | 8 | 1 | 4 |
| Yelhanka | 16 | 12 | 14 |
| Kumbalgode | 8 | 20 | 50 |
| Avalahalli | 24 | 18 | 26 |
| Bommasandra | 13 | 20 | 50 |

The fact that more quarries are facing environmental closure issues in Bangalore and these quarries need an alternate fuel for production; fueled by the reality that cost of material is directly proportional to the distance shows that processing C&D waste and C&D waste based building material is an acceptable model in Bangalore if feasible at reduced cost of production. The entrepreneurs are also open to change and are willing to accept new concepts if the technology and material are proven before them as technically and financially viable Business Model.


Figure 4: Bangalore city map

## Business Model

### Business Opportunities

The market analysis of building materials and raw materials reveals that cost of raw materials could be reduced by use of processed C&D waste instead of virgin materials which can be added to the minimal transportation cost. This inturn creates the market for C&D waste and C&D waste based building material products in Bangalore. Hence the financial and technical feasibility of different cases for better utilization of C&D waste is assessed in the below mentioned business models:

### Technical Specifications

*Processing of C&D waste*

The C&D waste mostly consists of broken bricks and concrete rubble in uneven sizes. The waste also consists of other materials including silt, stone rubble and ceramics. The C&D waste in order to be processed into aggregates of specific sieve size needs to be grinded (crushed) in crushing units similar to crushing of stones. Since the process of crushing remains the same, stone crushing machinery is used for the crushing of C&D waste. Hence the existing stone crushing machinery in the city (especially those facing shortage of access to raw materials) can be utilized for processing of C&D waste. Or else new units can be set up for the processing of the waste. Existing stone crushing units may need minor modifications for utilizing them for crushing C&D waste. The C&D waste crushing do not require the primary crushing which is used for crushing huge rock boulders into processable sizes and hence the feed entry need to be changed from the primary crusher to the secondary crusher. In addition, in many cases there is need for a fine material washing unit or a density air separator unit which might not be

available in the already existing facility and may need additional expenditure.

Business cases have been developed for medium size crushers, with a crushing capacity of 500 TPD and crushing on an average around 250-500 TPD and also larger crushers with an average maximum crushing capacity of 1000 TPD where an average of 500-1000 TPD of raw material is processed.

The size of the finished product is usually 20mm, 12mm, 10mm, 6mm and <4mm(dust), which can be retrieved according to the sieve arrangement at the outlet of the processing device that can be adjusted according to the need of the manufacturer. The business cases are developed for arrangements retrieving 10mm aggregates (passing through 12 mm sieve and retrieved in 10mm sieve) and dust particles (passing through 4mm sieve) alone. Once the C&D waste is processed into aggregates, they can be used instead of coarse and fine natural aggregates in manufacture of building materials and also for road works.

The paver block manufacturing industry utilizing C&D waste is the case considered in this study and hence the technical speculations of a paver block manufacturing unit is detailed below:

*Concrete Paver Block Manufacturing*

Concrete paving block is a building material used for laying pavements, footpaths, and other kind of exterior pathways for pedestrians and also for vehicular movement. They are widely accepted for their aesthetic features and ease of laying. They are available in various sizes, shapes, colors and strength grades (concrete mix) depending on the utility and aesthetic requirements. Some specific designs like the I-shaped 60mm thick paver block and Zig-Zag shaped 80mm thick paver block are always in demand in the market due to their interlocking properties (does not need binder) and load bearing properties while other designs like grass pavers, square pavers, etc are made only according to order and as per client requirements.

In Bangalore, it is observed that most of the paver block units are small or medium scale units which manufacture paver blocks in their own specific mix designs since the quality is rarely checked and more preference is given by clients to cost of the products.

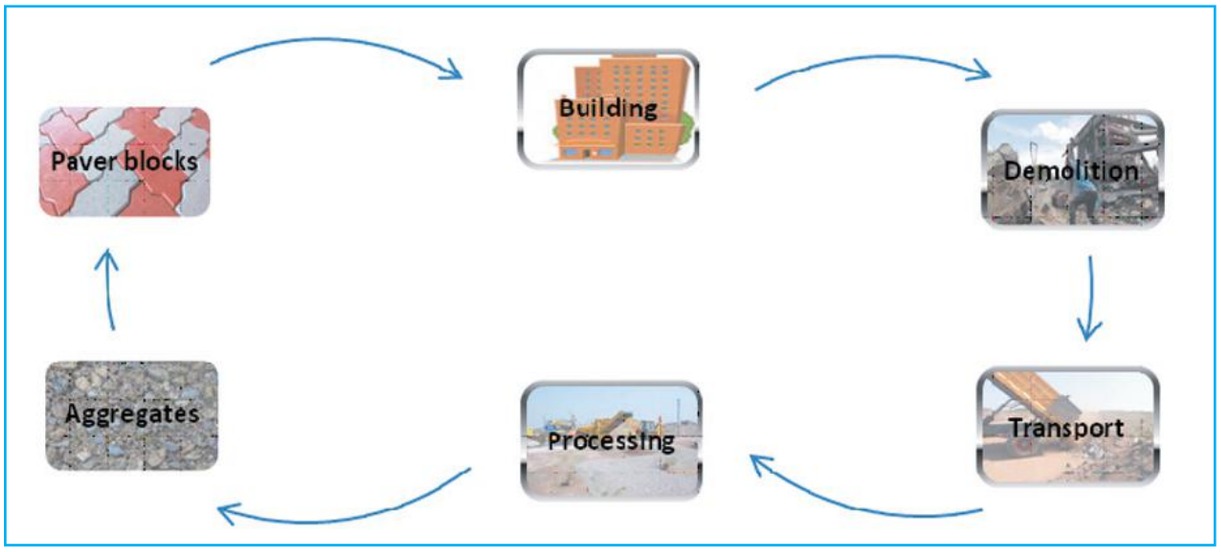



Figure 5: Proposed Model for secondary raw materials from recycling of C&D waste

12mm and 6mm aggregates are used as coarse aggregates, M-sand from quarries as fine aggregates; and dust is sometimes used for colour mixing for the top surface, and some time it is not. The change in raw materials includes use of same size coarse and fine aggregates made from processing C&D waste.

The business case is developed for a small scale enterprise with a manufacturing capacity of 2000 bricks per day using vibrating table technology inside the city and considered to be working at 75% efficiency. The business case also considers manufacturing of I shaped 60mm paver blocks (since from the market analysis it was observed that this is one of the most commonly manufactured kind of paver block, made and stocked due to market demand). The standard mix ratio adopted in this business case is the mix design suggested as per IS standards for manufacture of M15 grade equivalent paver blocks with a mix ratio of 1:1.84:3.31[1] which consists of 1 part of cement 1.84 parts of sand and 3.31 parts of 10mm aggregates. Initially the colour and concrete is mixed in a colour pan mixer and poured to a thickness of an average 5mm for surface coloring and vibrated in rubber or fiber mould to remove air gaps. Later the concrete mix is prepared in a concrete pan mixer and poured into the mix and vibrated in a second vibrator. The pavers are cured inside the mould for one day and then taken out after which final curing happens over a period of 10 days.

### Recommended Business models

In this study multiple scenarios have been identified where different entrepreneurs can utilise C&D waste or waste based raw materials in their business with or without additional investment. The business cases have been developed based on different size and scale of enterprises also.

The cases are developed based on several assumptions relating to ground reality. The assumptions are listed in Annexure 2.

The business cases are also compared with business as usual scenario utilising natural aggregates to highlight the financial difference involved due to change of raw material from natural materials to C&D materials. The recommended business cases include:

**Case 1** **Existing stone crushing entrepreneur process C&D waste into secondary aggregates and an existing paver block manufacturer utilizes the secondary aggregates into finished products**

The case applies for any stone crushing enterprise to change their raw materials from natural stone to C&D waste and sell the material to existing paver block manufacturing entrepreneur who also changes his raw material from virgin aggregates to C&D processed aggregates. This case does not involve any major investments.

**Case 2** **Existing stone crushing entrepreneur process C&D waste into secondary aggregates and also starting a new paver block manufacturing unit that utilizes the secondary aggregates**

The case applies for any stone crushing enterprise to change their raw materials from natural stone to C&D waste and also is interested in investing to start a small scale paver block manufacturing unit to utilise the processed C&D waste. In this case the major investment is required to setup the paver block unit.

**Case 3** **Existing paver block manufacturing unit that utilizes the secondary aggregates (with and without additional investment for mini-crushing unit)**

The case takes an assumption of an existing paver block manufacturing unit to utilise processed C&D waste aggregates, where the raw material is readily available in market or is processed in house using a mini crushing unit. In this case the major investment occurs for the paver block manufacturer for capital cost on the mini-crushing unit.

[1]Adopted from one of the enterprises visited during questionnaire survey in Bangalore


K.K.

### Case 4 New enterprise for C&D waste crushing and processing and new enterprise for paver block manufacturing utilizing the secondary aggregates

The case applies for a new entrepreneur who is interested in investing in a C&D waste processing enterprise and the material is utilised by a new enterprise (in-house or market sale cases considered) manufacturing paver block manufacturing from virgin aggregates to C&D processed aggregates. The case involves major investment for establishing the C&D processing unit and paver block manufacture unit.

### Case 5 New enterprise renting out mini-mobile crusher

The case considers a scenario in which an entrepreneur (public or private) invests in a mini-mobile crusher suitable to be transported easily to different demolition sites where C&D waste is crushed according to the needs of the client. The business model considers that the mini-crusher is rented out to the clients in Bangalore where the C&D waste is crushed in-situ and used in-house by the client. In this case the income for investor is through renting out the machine.

### Case 6 Mobile type mini-C&D waste crushing & processing enterprise providing rental services

In this case the entrepreneur (public or private) invests in a mini-mobile crusher suitable to be transported easily to different demolition sites where C&D waste is crushed transported back and stock piled by the entrepreneur in his stockyard. The processed material is later marketed by the entrepreneur. This is a mini-mobile version of the standalone crushing units.

Different business models are showcased in the study which is recommendable to be adopted by entrepreneurs in Bangalore. Even though the C&D waste generation inside the city is assumed to be 500 TPD by BBMP, field study reveals that there are huge number of unaccounted demolition debris being generated and disposed off in different pockets of the city. Hence even if the processing capacity of the existing plant is increased to maximum input, considering the logistic problems, it would not be feasible for the waste from many parts of the city to be transferred to the centralised plant.

Hence the decentralised models would be more suitable for better waste to resource utilization in the city and acceptability for implementation by the enterprises. Moreover the decentralised approach would enable processing of waste at the commercial centers as discussed in survey results that would minimize transportation of waste and resources. Case 5 & Case 6 in the business models proposed focus on decentralised approaches and hence would be more feasible, enabling mainstreaming of C&D as a resource in Bangalore.

The detailed cost derivations and comparisons of all business cases are attached as Annexure 1.

## Recommendations

There are many good practice initiatives implemented by BBMP for C&D waste management. Yet, their effectiveness can be enhanced through further activities, initiatives and gap filling duly considering C&D waste more as a resource than waste, which are given below as recommendations.

(1) PPP model C&D waste processing plants need to be implemented to process the waste, create business opportunities and revenue from the waste stream which is beneficial for all stakeholders involved.

(2) Different business cases are practical and profitable in Bangalore but decentralised type C&D processing units at different parts of the city, utilising the existing stone crushing units (Case 1) and the business model allowing mini-crushing units on a rental basis are most recommended models, since they involve minimal alterations to the existing systems.

(3) Only 3 dumping sites of the 8 are active. It should be ensured that waste is deposited at all 8 dumping units.

(4) The use of C&D waste also need to be upscale through developing better awareness on the use of C&D waste as a secondary raw material and its potential to generate income. The awareness has to be spread among different stakeholders including the ULB, stone processing unit enterprises, construction material manufacturers, builders, architects and even waste generators in order to develop sense of ownership, develop capacities and initiate action from all the stakeholders.

(5) Awareness activities in the form of round table meetings, stakeholder awareness workshops, capacity development workshops, circulars (from ULB to contractors and public), and other mass community mobilisation programs can be organised by BBMC and other government organisations.

(6) The quality of secondary construction materials can be ensured through eco labelling and other certification provided by national level organisations and other certifying bodies (like GRIHA) which will give proper value for the C&D waste based products. The certified materials could also be preferentially procured by government constructions. This will provide support for creating initial market and hence mainstream the products in the construction sector. Preferential procurement could be implemented through adding special clauses in tender documents for public projects.

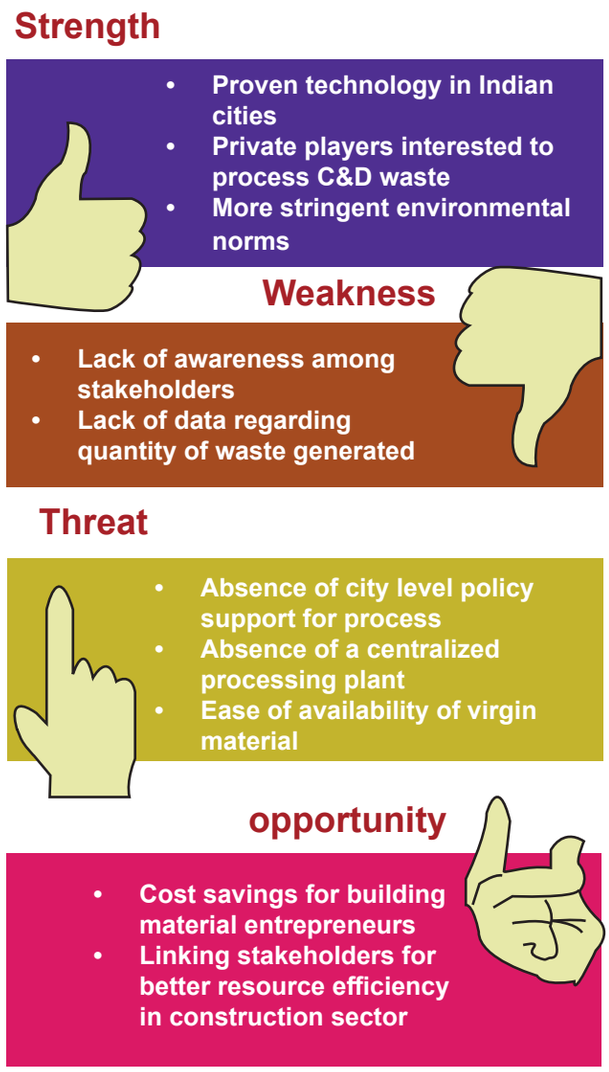
(7) More research and development activities need to be initiated focused on the use of fine particles (silt and clay) and other inert materials of C&D waste into recycle and reuse of construction and other allied sectors.

## Conclusion

The study shows that a potential market exits in Bangalore for secondary raw materials, the lack of awareness among the stakeholders and the lack of confidence to undertake a change in material (since its not a proven technology inside the city) has restricted the processing of C&D waste and its use as a secondary raw material. In addition, ease of availability of virgin raw materials and lack of a supportive city level policy also fuels to the resistance to change.

Private scale initiatives are seen in Bangalore for processing C&D waste, which need to be scaled up by integrating with the main system in order to obtain better resource efficiency in the construction industry of Bangalore.

The business case shows that the enterprises can manufacture equivalent quality secondary building material compared to primary materials at a much lower price. Hence the model will be of interest to entrepreneurs in financial terms. Secondary building materials from processed C&D waste if supported by green certifications and government procurement policies, can be promoted in Bangalore and a proper market can be created through planned promotion and IEC activities.



## Annexure 1 – Business cases

**Case 1: Existing stone crushing entrepreneur replace natural raw material completely or partially (10%, 25% & 50%) and process C&D waste into aggregates and an existing paver block manufacturer utilizes the secondary aggregates into finished products**

| STONE CRUSHING UNIT | | | | | |
|---|---|---|---|---|---|
| **Processing capacity (T/d)** | 400 | | | | |
| **Products** | Aggregates (12mm, 6mm, <4mm) | | | | |
| **Financials** | **Processing natural aggregates (INR/day)** | **Processing C&D aggregates by 10% replacement (INR/day)** | **Processing C&D aggregates by 25% replacement (INR/day)** | **Processing C&D aggregates by 50% replacement (INR/day)** | **Processing C&D aggregates by 100% replacement (INR/day)** |
| **Capex** | 0 | 607,475 | 1,201,475 | 2,191,475 | 4,171,475 |
| Material stock load[i] | | 396,000 | 990,000 | 1,980,000 | 3,960,000 |
| Machinery[ii] | | 211,475 | 211,475 | 211,475 | 211,475 |
| **Opex (per day)** | 106,127 | 103,817 | 100,352 | 94,577 | 81,239 |
| Material Cost | 88,000 | 85,800 | 82,500 | 77,000 | 66,000 |
| Other cost[iii] | 18,127 | 18,017 | 17,852 | 17,577 | 15,239 |
| **Cost of production[iv]** | 116,739 | 114,978 | 111,929 | 106,847 | 94,716 |
| **Cost of production (per ton)** [v, vi] | | | | | |
| Aggregates (6mm, 12mm) | 88 | 86 | 84 | 80 | 71 |
| Aggregate sand ( < 4mm) | 204 | 201 | 196 | 187 | 166 |

| COST SAVINGS BY CHANGE OF RAW MATERIAL | | | | | |
|---|---|---|---|---|---|
| **Specification** | **Processing natural aggregates (INR/day)** | **Processing C&D aggregates by 10% replacement (INR/day)** | **Processing C&D aggregates by 25% replacement (INR/day)** | **Processing C&D aggregates by 50% replacement (INR/day)** | **Processing C&D aggregates by 100% replacement (INR/day)** |
| **Cost saving per day (INR)** | | 1,761 | 4,811 | 9,893 | 22,023 |
| **Cost savings per ton of aggregates (INR)** | | 1 | 4 | 7 | 17 |
| **Cost savings per ton of sand (INR)** | | 3 | 8 | 17 | 39 |
| **Cost reduction per day** | | 2% | 4% | 8% | 19% |
| **Payback period (months)** | | 14 | 10 | 9 | 8 |

| PAVER BLOCK MANUFACTURING UNIT | | |
|---|---|---|
| **Processing capacity (T/d)** | | 2000 |
| **Products** | Paver Blocks ( M25 Grade, I-shaped) | |
| **Financials** | **Utilising natural raw materials (INR/day)** | **Utilising recycled raw materials (INR/day)** |
| **Capex** | 0 | 0 |
| **Opex (per day)** | 11,583 | 11,399 |
| Material Cost | 8,441 | 8,266 |
| Other cost | 3,142 | 3,133 |
| **Cost of production per day** | 12,741 | 12,539 |
| **Cost of production per day per block** | 6.4 | 6.3 |
| **Cost of production per day per sq.ft** | 20.4 | 20.1 |
| | | |
| **Cost saving per day (INR)** | 184 | 1.44%<br>Cost reduction per day |
| **Cost savings per block (INR)** | 0.10 | |
| **Cost savings per sq.ft (INR)** | 0.32 | |

**Case 2: Existing stone crushing entrepreneur replace natural raw material completely and process C&D waste into aggregates and invest on a new paver block manufacturing unit that utilizes the secondary aggregates to make finished products**

| STONE CRUSHING UNIT | | |
|---|---|---|
| **Processing capacity (T/d)** | | 400 |
| **Products** | Aggregates (12mm, 6mm, <4mm) | |
| **Financials** | **Processing natural aggregates (INR/day)** | **Processing C&D aggregates (INR/day)** |
| **Capex** | 0 | 4,171,475 |
| Material stock load | | 3,960,000 |
| Machinery | | 211,475 |
| **Opex (per day)** | 106,127 | 81,239 |
| Material Cost | 88,000 | 66,000 |
| Other cost | 18,127 | 15,239 |
| **Cost of production** | 116,739 | 94,716 |
| | | |
| **Cost of production (per ton)** | | |
| Aggregates (6mm, 12mm) | 88 | 71 |
| Aggregate sand ( < 4mm) | 204 | 166 |

| COST SAVINGS BY CHANGE OF RAW MATERIAL | | |
|---|---|---|
| **Cost saving per day (INR)** | 22,023 | 19%<br>Cost reduction by change of raw materials |
| **Cost savings per ton of aggregates (INR)** | 17 | |
| **Cost savings per ton of sand (INR)** | 39 | |
| **Payback period for capex (Months)** | 8 | |

| PAVER BLOCK MANUFACTURING UNIT | | |
|---|---|---|
| **Processing capacity (T/d)** | 2000 | |
| **Products** | Paver Blocks ( M25 Grade, I-shaped) | |
| **Financials** | **Recycled aggregates based products (Standalone unit with outsourced materials) (INR/day)** | **Recycled aggregates based products (Integrated unit with inhouse materials) (INR/day)** |
| **Capex** | 1,034,550 | 1,034,550 |
| **Opex (per day)** | 11,399 | 10,964 |
| Material Cost | 8,266 | 8,092[vii] |
| Other cost | 3,133 | 2,872 |
| **Cost of production per day** | 13,866 | 13,346 |
| **Cost of production per day per block** | 6.9 | 6.7 |
| **Cost of production per day per sq.ft** | 22.2 | 21.4 |

| COST COMPARISON OF INHOUSE PAVER UNIT TO STANDALONE UNIT | | |
|---|---|---|
| **Cost saving per day (INR)** | 520 | 4%<br>Cost reduction for inhouse unit than standalone unit |
| **Cost savings per block (INR)** | 0.26 | |
| **Cost savings per sq.ft (INR)** | 1 | |

| ADDITIONAL PROFIT PER DAY BY ESTABLISHING THE PAVER BLOCK UNIT | | |
|---|---|---|
| **Specifications** | Along with crusher | Standalone unit |
| **Number of Blocks per day** | 2000 | 2000 |
| **Paver block (per sq.ft)** | | |
| Cost Price (INR) | 21.4 | 22.2 |
| Selling price (INR) | 25.6 | 26.6 |
| Profit (INR) | 4.3 | 4.4 |
| **Total profit per day (INR)** | 8,541 | 8,874 |
| **Payback period (Months)** | 5 | 5 |

**Case 3: Existing paver block manufacturing unit that utilizes the C&D waste secondary aggregates with and without additional investment to make recycled aggregates**

| PAVER BLOCK MANUFACTURING UNIT | | | |
|---|---|---|---|
| **Processing capacity (T/d)** | 2000 | | |
| **Products** | Paver Blocks ( M25 Grade, I-shaped) | | |
| **Financials** | **Utilising natural raw materials (INR/day)** | **Utilising recycled raw materials (INR/day) outsourced** | **Utilising recycled raw materials (INR/day)** *inhouse* |
| **Capex** | 0 | 0 | 200,000 [viii] |
| **Opex (per day)** | 13,109 | 12,917 | 12,029 |
| Material Cost | 9,895 | 9,711 | 8,515 |
| Other cost | 3,214 | 3,205 | 3,514 |
| **Cost of production per day** | 14,420 | 14,208 | 14,158 |
| **Cost of production per day per block** | 7.2 | 7.1 | 7.1 |
| **Cost of production per day per sq.ft** | 23.1 | 22.7 | 22.7 |

| COST SAVINGS BY CHANGE OF RAW MATERIAL | |
|---|---|
| **Per block (INR)** | 0.11 |
| **Per Sq.ft (INR)** | 0.34 |
| **Per day (INR)** | 212 |
| **Profit by change of raw material** | 1% |

**Case 4: New stone crushing entrepreneur process C&D waste into aggregates and a new paver block manufacturing enterprise utilizes the secondary aggregates into finished products**

| STONE CRUSHING UNIT | |
|---|---|
| **Processing capacity (T/d)** | 400 |
| **Products** | Aggregates (12mm, 6mm, <4mm) |
| **Financials** | (INR/day) |
| Capex | 12,028,050 |
| Material stock load | 3,960,000 |
| Machinery | 8,068,050 |
| **Opex (per day)** | 81,239 |
| Cost of production (per day) | 104,799 |
| Cost of production (per ton) | |
| Aggregates (6mm, 12mm) | 79 |
| Aggregate sand ( < 4mm) | 183 |
| **Selling price (per ton)** | |
| Aggregates (6mm, 12mm) | 92 |
| Aggregate sand ( < 4mm) | 215 |
| **Profit (per ton)** | |
| Aggregates (6mm, 12mm) | 13 |
| Aggregate sand ( < 4mm) | 32 |
| **Profit (per day)** | |
| Aggregates (6mm, 12mm) | 3,216 |
| Aggregate sand ( < 4mm) | 5,056 |
| **Net Profit (per day)** | 8,272 |

| PAVER BLOCK MANUFACTURING UNIT | |
|---|---|
| **Processing capacity (T/d)** | 2000 |
| **Products** | Paver Blocks ( M25 Grade, I-shaped) |
| **Financials** | **Utilizing natural raw materials (INR/day)** |
| **Cost Price** | |
| **Capex** | 1,001,550 |
| **Opex (per day)** | 11,029 |
| **Cost of production (per day)** | 13,417 |
| (per paver block) | 7 |
| (per sq.ft) | 21.5 |
| **Selling price** | |
| (per paver block) | 10 |
| (per sq.ft) | 31 |
| **Profit** | |
| (per paver block) | 3 |
| (per sq.ft) | 9 |
| **Net profit** (per day) | 5,904 |

| | |
|---|---|
| **Gross profit per day** | 14,176 |
| **Payback period (months)** | 37 |

**Case 5: Mobile type mini-C&D waste crushing & processing enterprise providing rental services**

| C&D WASTE MINI-CRUSHING UNIT (50 TONS PER DAY) | |
|---|---|
| No: of working days per annum | 200 |
| Output Materials | 6mm-12mm aggregates |
| | < 6mm aggregates (M-sand) |
| Rated Capacity (Tons/day) | 65 |
| Production capacity ( Tons /day) | 50 |
| Working Hours per day | 8 |
| **Capex** | |
| Machinery | 1,203,000[ix] |
| **Opex (per day)** | |
| Depreciation on machinery (10% / annum) | 602 |
| Electricity & Fuel | 3730 |
| Manpower | 480 |
| Transport | 3000 |
| Additional cost | 210 |
| **Total** | 8,022 |
| Cost of production per day (Capex + Interest + Opex) | 9,425 |
| Total Cost | 10,368 |
| **Equivalent aggregate cost (6mm-12mm) per ton** | 174 |
| **Equivalent dust cost ( .75 - 6mm ) per ton** | 75 |
| **Rent of Machine per hour** | **1555** |
| **Rent of Machine per day** | **12441** |
| **Profit per day** | **2074** |
| **Payback period (Months)** | 23 |

[i] Raw material stock load cost for a period of 50 days

[ii] Cost of implementing a magnetic separator system from removing the metallic waste from the input C&D waste and also implementing the support structures for changing the input feed of the materials

[iii] Other cost include Machinery cost, Manpower cost, miscellaneous cost, depreciation cost & additional unexpected cost (which is a factor of total cost including material cost)

[iv] Cost of production includes Operating cost (Opex) as well as regular payback amount of loan. Refer assumptions

[v] Cost of production at factory excluding transport cost

[vi] 30% output is aggregate stone and 70% is sand

[vii] Costs less since enterprise utilize material produced inhouse and hence not receiving material at selling price (only cost price calculated)

[viii] Paver block manufacturing enterprise just purchase a Jaw crusher and manual sieve to crush and use C&D waste as raw material for his product

[ix] All machinery costs are based on original quotations received by Author from enterprises providing similar machinery

**Case 6: Mobile type mini-C&D waste crushing & processing enterprise providing rental services**

| C&D WASTE MINI-CRUSHING UNIT (50 TONS PER DAY) | |
|---|---|
| No: of working days per annum | 200 |
| Output Materials | 6mm-12mm aggregates |
| | < 6mm aggregates (M-sand) |
| Rated Capacity (Tons/day) | 65 |
| Production capacity ( Tons /day) | 50 |
| Working Hours per day | 8 |
| **Capex (INR)** | |
| Machinery (INR) | 1,203,000 |
| **Opex per day (INR)** | |
| Depreciation on machinery (10% / annum) | 602 |
| Electricity & Fuel (INR) | 3730 |
| Manpower (INR) | 480 |
| Transport (INR) | 6000 |
| Additional cost (INR) | 210 |
| **Total (INR)** | 11,022 |
| Cost of production per day (Capex + Interest + Opex) (INR) | 12,425 |
| **Total Cost (INR)** | 13,668 |
| **Total cost per ton (INR)** | 273 |
| **Cost price of aggregate (6mm-12mm) per ton** (INR) | 191 |
| **Cost price of sand ( .75 - 6mm ) per ton (INR)** | 82 |
| **Selling price of aggregate (6mm-12mm) per ton** (INR) | 230 |
| **Selling price of dust ( .75 - 6mm ) per ton** (INR) | 98 |
| **Profit per day** (INR) | **2734** |
| **Payback period (Months)** | 18 |

## Annexure 2 – Assumptions

⇒ The cost of collection and transport of C&D waste to the crusher enterprise is considered Rs150/ton[3].

⇒ Cost of 50kg cement bag considered as INR 350/-

⇒ 70% of output from crusher unit is course aggregates and 30% of output is fine aggregates (quarry dust)[4]

⇒ The enterprise establishment capital expenditure cost is considered to be made on a bank loan of 15% for a period of 5 years

⇒ The cost of labour is referred from costing of Labour commission and MSME documents(MSME, 2010)(MSME, 2010)

⇒ The cost of machinery is referred based on secondary data collected from entrepreneurs in Bangalore and invoices received for new machinery[5]

(Red Rhino Crushers, 2016)(Shanghai Zenith Mining and Construction Machinery Co., 2016)(Henan HongXing Mining Machinery Co., 2016)(Star Trace, 2016)(TARA Machines Pvt Ltd, 2016)

⇒ The efficiency of the processing machinery is considered as 80%[6]

⇒ Depreciation cost of building considered to be 5% per annum

⇒ It is assumed that the entrepreneur owns their own land (or land is available) to start the enterprise and no additional cost for land is considered

⇒ Depreciation cost of machinery considered to be 10% per annum

⇒ Electricity cost calculated using latest Industrial rate slabs(UGVCL)

⇒ 10% additional charges are provided for C.P considering manufacturing losses

⇒ Selling price of normal paver block (I shaped,60mm thick, M30 grade) in market is Rs 25 per Sq.ft[7]

⇒ One way Transport cost of materials from or to outside the city region is considered Rs 250 per Ton (Considering a 16 Toner truck with carrying capacity of 12 Tons and transporting at Rs 3000 per truck load for an average distance of 100 Kms)

⇒ The paver block manufacturers use 10mm aggregates as coarse aggregates[8]

⇒ Cost of river sand is Rs 450 per Ton

[3]Based on rate of collection by AEP.Pvt Ltd in Ahmedabad
[4]Based on interaction with enterprises in Bangalore
[5]Based on interaction with enterprises in Bangalore
[6]Based on interaction with enterprises in Bangalore
[7]As per market rate on May 2016
[8]Based on interaction with enterprises in Bangalore

⇒ Selling price of aggregate by a newly setup enterprise is considered equivalent to the selling price adopted by existing enterprises

⇒ The Enterprises under business as usual scenario are working at a profit margin of 10%[9]

⇒ Total number of working days is considered as 200 days per annum for crushing industry and 250 days for paver block manufacture industry

⇒ Average weight of I-shaped 60mm paver considered as 4.5kg per block

⇒ Stock pile of new raw materials is considered for 60 days in advance

[9]As per market rate on May 2016

## Annexure 3 – Basic information on building materials in Bangalore

| Material | Usual Grades | dimensions | Raw Materials | Cost | Manufacture Process |
|---|---|---|---|---|---|
| **I-Shaped Paver Block** | M20 | | Aggregates (12mm, 6mm), M-Dust, Cement | 35 Rs/sq.ft | Hydraulic Press Process, Vibration Process |
| **I-Shaped Paver Block (BIS Marked)** | M40 | | Aggregates (12mm, 6mm), M-Dust, Cement | 120 Rs/sq.ft | Hydraulic Press Process |
| **Concrete Block (4" Block)** | M20 | 4"x 8"x16" | Aggregates (12mm, 6mm), M-Dust, Cement | 24 Rs/brick | Hydraulic Press Process, Vibration Process |
| **Concrete Tiles** | M15 | 12" x 12" | Aggregates (6mm), M-Dust, Cement | 25 Rs/piece | Vibration Process |
| **Kerb Stones** | M20 | | Aggregates (12mm, 6mm), M-Dust, Cement | 180 Rs/ Running meter | Hydraulic Press Process, Vibration Process |

## Annexure 4 – Questionnaire for Stakeholders

### Urban Local Bodies & Contractors

1. What is the quantum of C&D waste that is collected per day inside governance area (Tons/Day)?
2. What is quantum of construction and demolition in the region (sq.m per year)?
3. Does the quantity of waste depend on seasonal variations, if Yes then please elaborate? How did the quantum of C&D waste changed during the past years / Do you have statistics on monthly/ yearly gathered C&D waste?
4. How/When is the C&D waste collected? Who is the responsible contact person?
5. What is the minimum quantity of waste which is collected? Process Flow?
6. How is the cost of managing C&D waste recovered (eg – tariff, tax etc)?
7. Have the C&D waste been characterized? If Yes what is the detailed breakup of components in percentage? If not, rough estimations of composition – element wise?

   As options for recycling mainly depend on the strength of the components, it would be helpful for our future work to gather the different components classified by strength

| Component | Estimated share (%) |
|---|---|
| Natural stones and gravel | |
| Fragments of concrete | |
| Hard burned bricks, ceramics | |
| Soft burned bricks (if there are in India?) | |
| Sand-lime stones | |
| Aerated/light weight concrete | |
| Mortar, plasters, etc. | |
| Adobe | |
| | |
| Other, please specify (e.g. metals, glass, wood, plastics, bituminous fractions, …) | |

8. Is there any check or analysis for detecting other materials in C&D waste and quality of C&D waste (if it is to be processed)?
9. What is the C&D waste management policy of the ULB? Is there any program or scheme to support C&D waste management?

   (a) Is there is a C&D landfill in operation. If yes what is the capacity of the landfill? How much of it is fill and for how many years it will remain operational? 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? Are the fractions of C&D waste separated, if yes: how? What percentage? Are the recycled/reused products marketed? If Yes details? If not, is there a potential? And for what kind of materials in which form?

   (c) Are valuables from C&D waste collected by rag pickers during the process of collection and transportation, if yes which components? What percentage?
10. 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? What are the payment terms with the private entity?

11. 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? What are the payment terms with the private entity?

    (b) If there is a processing facility then was it built on any special fund?

12. How and where is the C&D waste disposed? What is the technology used? Is the C&D waste separated and is some of the fractions further processed/recycled? If yes: what kind of products/ recycled materials do they produce and who uses/where are the products/recycled materials 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?
13. 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?
14. How is the competition in this field?
15. 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 the points?
16. Are you interested in implementing better C&D reuse and management programs?

    (a) Are enough IEC activities been 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 state government in the new budget which could be utilized for development of C&D waste management services?

    Is there any support provided by bank or is it available on request? if Yes then details?

**C&D Waste Managers / Processing Enterprises**

1. What is the total C&D waste generated in the city and what is the quantum collected?
2. What is the total quantum of waste managed/ processed by the particular unit?
3. What is the reusable quantum / percentage of waste?
4. What is the characterization of waste?
5. What is the flow materials of C&D waste from source to product/landfill?
6. How the management charges retrieved? What the contract clauses?
7. What is the major processing done? What is the end product and what is the use of end products?
8. What are the capex and opex charges?
9. Is the business financially profitable?
10. What is the kind of technical and marketing support that is required to help the business?
11. What are the policy changes that you suggest to help the recycling of C&D waste?
12. What are the factors the C&D waste characteristics and quantum depend on?
13. If there is a material change/ technology change option available, then what is minimal additional profit margin for which it will be adopted?
14. Is the quality of product according to national standards? If Yes, then has it been tested? If No, Why not? Will the test results be shared or samples be provided for testing?

15. Would a centralized or decentralized approach be more suitable for the city for C&D waste management? (briefly explain)

**Developers**

1. What is the demolition technique used? Technique used for each kind of building? How much waste generated per unit area / per unit time? Do you have a calculation on construction / demolition waste per unit area been made? (Even a rough calculation would be appreciated)
2. What is the component percentage breakup (or the major components) in each category of building? What percentage of each component waste gets reused? What is the usual percentage cost saving involved of each component?
3. Is the C&D waste load quantified before clearance?
4. Is the demolition process outsourced or in-house resources are used? If outsourced then what is process of outsourcing?
5. Have the C&D waste been characterized? If Yes what is the detailed breakup according to the type of building? If Not what is rough estimate& which are main components?
6. What is the C&D waste management practice in 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 rest of the developers?
    a. Do you know that open dumping is bad for the environment?
    b. Do you engage professionals or Contractors for demolition / construction/ renovation purposes?
    c. 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?
    d. Is any part of C&D waste sold to scrap, if Yes then how and what percentage?
    e. 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)?
7. Is any waste reduction practice followed during construction or demolition process? If Yes please brief it? If Yes then are the laymen trained to do so?
8. Do you wish for a change in the present C&D waste management practices? If Yes please brief a few points?
9. What is the growth potential of the city (with reference to land availability, land cost, resources and activities) in terms of construction?
10. 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)
11. Do you wish to use building materials made out of C&D waste? If yes: what kind of advantages do you see (e.g. much less costlier), if no: what kind of disadvantages do you see (e.g. no harmonized product standards)? What kind of recycled materials would you use, what kind of recycled materials do you reject to use and why?

### Stone Crushing Units

1. What is the capacity of the crushing unit?
2. What is the operating efficiency?
3. What is the different size of products manufactured? Which materials have maximum demand in market?
4. What are the rough capex and opex charges for manufacture?
5. If there is a material change/ technology change option available, then what is minimal additional profit margin for which it will be adopted?
6. What is the technical and policy support required for better business?
7. What are the environmental or mining legal constraints faced that hinder the business?
8. Is the entrepreneur ready to make additional investments if profit margin can be increased?

### Material Manufacturers

1. What are the Plain Cement Concrete construction materials that have a strong market in the city?
2. What are the materials processed in your company? What is the capacity of your processing plant? Operation efficiency?
3. What are the capex and opex charges?
4. What is the kind of technical and marketing support that is required to help the business?
5. If there is a material change/ technology change option available, then what is minimal additional profit margin for which it will be adopted?
6. What is the source of raw materials and technology used (brief)?
7. What is the transport cost of finished products and raw materials?
8. What s expected to be the acceptance of the materials if there is a change in raw materials from virgin to recycled materials (if it has been technically and financially proven compatible)?
9. Has any innovative technology or raw-material been tried for the manufacture of the product?
10. Is the quality of product according to national standards? If Yes, then has it been tested? If No, Why not? Will the test results be shared or samples be provided for testing?

### Technical Experts

1. What are the commonly used reuse or recycle technologies and products used in the region regarding construction materials? What kind of advantages and disadvantages of the reused/ recycled technologies / products do you see? Do you see option for improving the existing technologies/ products?
2. 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?
3. 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?
4. What kind of technology / product should be further developed in order to improve reuse/recycling construction materials?
5. What is the kind of technical and policy support given to different stakeholders to increase use of recycled materials in construction?

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## End notes

[1] Raw material stock load cost for a period of 50 days

[2] Cost of implementing a magnetic separator system from removing the metallic waste from the input C&D waste and also
implementing the support structures for changing the input feed of the materials

[3] Other cost include Machinery cost, Manpower cost, miscellaneous cost, depreciation cost & additional unexpected cost (which is a
factor of total cost including material cost)

[4] Cost of production includes Operating cost (Opex) as well as regular payback amount of loan. Refer assumptions

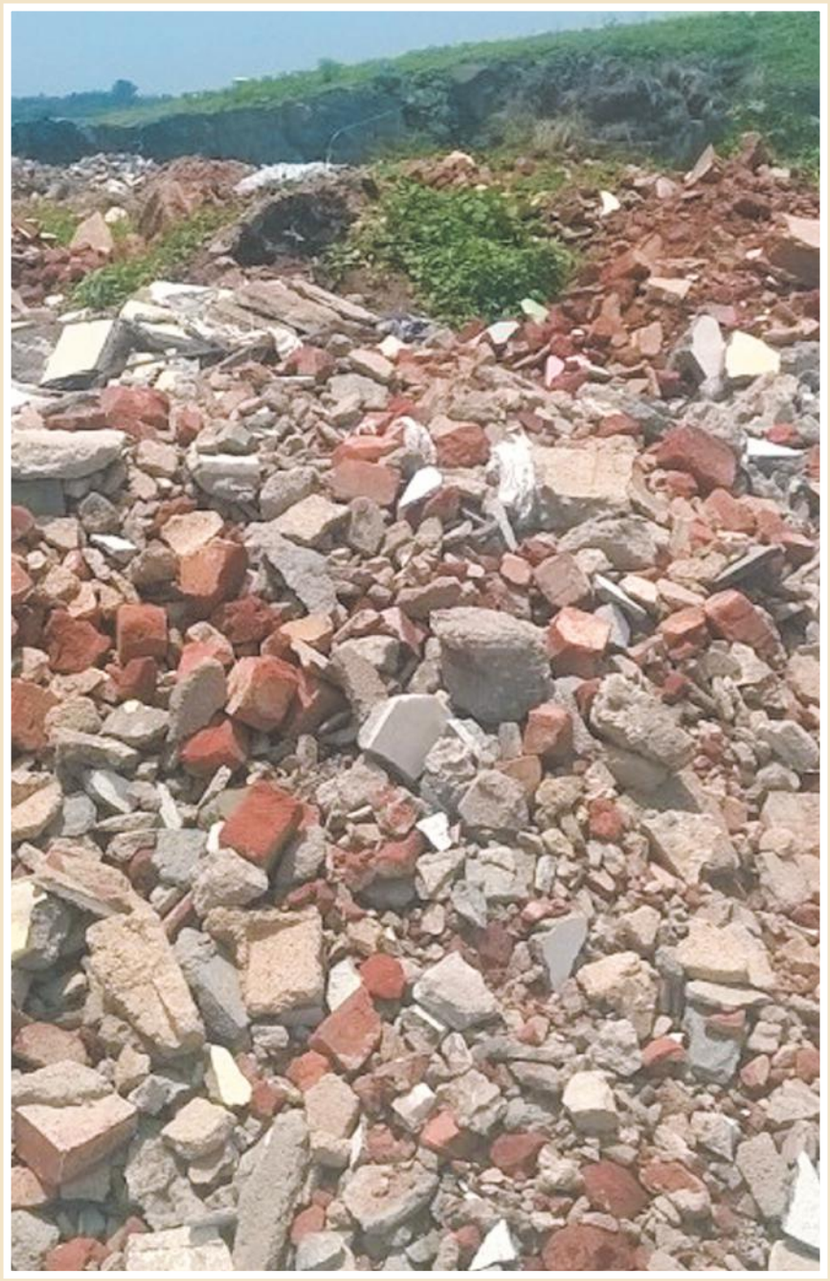
[5] Cost of production at factory excluding transport cost

6 30% output is aggregate stone and 70% is sand

[7] Costs less since enterprise utilize material produced inhouse and hence not receiving material at selling price (only cost price calculated)

[8] Paver block manufacturing enterprise just purchase a Jaw crusher and manual sieve to crush and use C&D waste as raw material for
his product

[9] All machinery costs are based on original quotations received by Author from enterprises providing similar machinery. Refer Annexure 2



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