Slum development using zero waste concepts

Priyanshu Prawal Thakuria [1], Dr. Madhumita Roy [2] and Dr. Arpan Dasgupta [3]
[1, 2] Jadavpur University, Kolkata, India
priyanshuprawal@yahoo.co.in, madhumi_r@yahoo.co.in
[3] Amity University, Kolkata, India
adgupta@kol.amity.edu

Abstract: Whenever any policies are made for the eradication of the slums, it is always observed that it takes a substantial amount of time in understanding the same. Thereafter when the actual implementation starts at ground, because of many valid reasons, nil initiatives/attempts are taken by the authorities in exploring the alternative materials/technologies into these projects. As a result, the projects are executed using conventional materials without considering environmental hazards. Government of India has taken an initiative in which affordable housing will be provided to the slum dwellers with a target of building 20 million affordable houses by March 2022. The increasing demand for material supply in construction industry has become a concern and on the other hand construction wastes and debris is another headache. Both the activities are considered as major contributors of environmental pollution. Keeping this in mind, it is advisable to go for the concept of 3Rs i.e. Reducing, Recycling & Reusing the waste generated from construction and demolition activities for the purpose of new construction. This study will assess the quantum of construction waste generation in a slum redevelopment site which can be reused, recycled for implementing the Affordable Housing schemes for the slum dwellers.

Keywords: Slum; C&D waste; Recycle; Construction.

1. Introduction

Food, clothes and shelter are the three basic needs non fulfilling of which tall claims of progress by any government projects a fake reality. India, which is one of the fastest growing economy in the world and one of the fastest developing countries of the world, yet ground realities suggests there are millions homeless, especially in the urban areas.

In Guwahati alone, in the year 2010-11, around Rs. 10 crore was spent for the upgradation of the existing slums through BSUP project but the condition and the number of slums still remains the same. As per Rajiv Awas Yojana (RAY) draft Slum Free City Plan of Action, a total of around 170 slums have been identified in the city of Guwahati, covering an area of approximately 1.28 sq. km with a total slum population of 90500. The slum population amounts up to 9 percent of the total population of city of Guwahati. 37 percent of the slums in Guwahati came up in the past 45 years. On an average there is an increase of 12 new slums per decade in Guwahati. The oldest slum in Guwahati is about 130 years old and three slums are more than 100 years old.

More than 20 slums are 21 - 30 years old and most of the slums are in core areas of the city. In many cases, in Guwahati alone, the slums have come up in the hills which has resulted in the unauthorized cutting of the hills resulting in serious threat of landslides and artificial floods.

As per Census of India, the definition of Slum has evolved based on the present condition of the urban poor. Presently the definition of slum adopted is as “Residential areas where dwellings are unfit for human habitation by reasons of dilapidation, overcrowding, faulty arrangements and design of such buildings, narrowness or faulty

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arrangement of street, lack of ventilation, light, or sanitation facilities or any combination of these factors which are detrimental to the safety and health."

The rate of increase of the urban population in India is higher than the normal overall population. With over 575 million urban populations, India will have 41% of its population living in cities and towns by 2030 from the present 28% of the population totaling 286 million. Due to rapid urbanization, the number of slum dwellers is rising in Indian cities. The slum population has increased from 27.9 million in 1981 to over 40 million in 2001 to a whopping 65 million in 2011.
60% of India's GDP comes from cities and the bulk of city services is provided by the informal sector, and yet it is to be noted that in most of the development projects, a quarter of the urban population is excluded. Another important aspect is that, in most of the cities of India, where slum dwellers constitute 25%-40% of the city population, they rarely occupy more than 3%-5% of the city space. Also, in India, it has been observed that most of the slum up-gradation policies the architectural and the planning guidelines are not followed to the point. In most cases, the schemes are made on a holistic approach in which the entire country has a uniform guideline. India being very vast county, the problems in all the states are different, each possessing a unique characteristic. Due to this, most of the schemes have failed to address the real problems in slum eradication in a particular state or territory. Also all the states have different architectural styles. In most of the schemes, there is no proper justification for the allotment of the sizes of the dwelling units or the basic services that are to be provided in the houses.

1.1 Novelty/Innovation and methodology

Providing affordable shelter to the people living in slums has been always an ambitious target by the Government. Whenever any policies and program are proposed by the government, it is observed that in most of the times a substantial amount of time is taken in understanding the same. Thereafter when the implementation starts at ground because of many valid reasons, no initiatives are taken by the implementing agencies in exploring the alternative materials and technologies into these projects. As a result, the projects are done using conventional materials in most of the cases causing environmental hazards.
Government of India has taken an initiative in which affordable housing will be provided to the slum dwellers with a target of building 20 million affordable houses by March 2022. On one hand, the increasing demand for raw material supply in construction industry has become a major concern and on the other hand - handling Construction & Demolition waste is a serious botheration. Both the activities are considered as major contributors of environmental pollution. Keeping this in mind, both government and designers/engineers are aiming to go for the concept of 3 R's *i.e.* Reducing, Recycling & Reusing the waste generated from construction and demolition activities for the purpose of new construction. This study will assess the quantum of waste generation in a slum pocket which can be reused, recycled for implementing the Affordable Housing schemes for the slum dwellers.
Traditionally, waste reduction in design and built environment settings was a response to legislation and rising landfill costs. As a result, although materials are diverted from landfill, their value is often degraded, preventing them from re-entering the system (for example, downcycling materials to aggregates for construction fill or recovery as refuse derived fuels (RDF). With resource scarcity becoming a clear threat to current operating systems, preventing waste at source through design is a priority. As many construction materials are considered to be of low value, any actions aimed at recovery are seen as an added cost. Therefore, the idea of circular economy design should be applied from the inception of any project.

1.2 Circular economy design

The circular economy is one that's sustainable and eliminates waste to the maximum possible extent. It's about developing new business models, designing smart products, remanufacturing and reprocessing to create new products from old, and repairing what we can – all to keep products and materials within the economy for as long as possible. Designing out of waste is one of the key codes of the circular economy – a concept inspired by observing the flow of resources in nature. In the living world, there is no landfill for waste materials and resources flow in a cyclical way. Many sectors, including construction, operate largely within a linear economy model, which assumes resources are abundant and we can make, use and dispose them without consequences. Policy makers are now looking at more sustainable and restorative models, which will allow resources to flow in a circular way, eliminating waste wherever possible.

There are several fundamental principles that underpin circular economy thinking. Table 1 demonstrates how these concepts can be applied to the construction and built environment sector, and emerge as opportunities for designing out waste.

Table 1. Circular economy principles and related designing out waste opportunities

Circular economy principles	**Example designing out waste opportunities**
Prevention	Design for sequential access to relevant services to prevent material damage during maintenance and repair
Share	Allow flexibility within design to acquire unconventional items if necessary and to allow for the potential for material exchange
Life extension	Design to use durable components and fixings
Re-use	Prioritize the sourcing and use of re-used materials
Refurbishment/ remanufacture	Consider the use of temporary or reloadable structures
Open-loop recycling	Design to specify the use of recycled materials where possible

There are five key principles around how to design out waste. They play their part in effective implementation of Circular Economy -

i) **Design for waste-efficient procurement** - This is a facet of the efficient management of the overall construction process. It involves early and ongoing communications between clients, design teams, contractors and sub-contractors, and a review of any specifications that may restrict waste reduction options. If departures from standard specifications are required to enable waste reduction, these are more readily implemented if identified by the design team and discussed with the client and contractor.

ii) **Design for materials optimization -** This principle focuses on making the most efficient use of resources without compromising design or quality. Design solutions that lead to a significant reduction in waste generated and costs consider the minimization of excavation, simplification and standardization of materials and components, and dimensional coordination.

iii) **Design for off-site construction -** The concept of industrialized prefabricated building, based on the principle that as much of the work as possible is done in a factory environment, leaving simple assembly operations to take place on site, is not a new one. Off-site construction can result in changes to on-site practice and may require different specialist skills. Therefore, it should be specified early in the design process. Off-site manufactured components should incorporate the principles of designing out waste in their own design.

iv) **Design for re-use and recovery** - This principle focuses on the whole life cycle of the materials used, extending their life and preparing for recovery. Actions relating to this can involve re-using existing structures on site, sourcing reclaimed products such as roof slates or timber components, excavation arising (such as using intelligent cut-and-fill methods to minimize waste generation and the need for virgin materials) or crushed demolition materials.

v) **Design for deconstruction and flexibility** - Design for flexibility of use and deconstruction, as well as climate adaptation, is a principle focusing on the whole life cycle of the building and is strongly linked to the design for re-use and recovery principle as it allows for materials to be re-used at the end of their life. Examples of this idea can include the use of partitions to allow spaces to be reconfigured or the use of bolts instead of adhesives for deconstruction.

According to the World Green Building Council the construction sector accounts for up to 40% of waste in landfill sites worldwide. The National Waste Information Baseline Report indicates that the construction sector is responsible for 8% of all waste generated, although it is unclear whether this number includes the waste from product suppliers during production, which is significant. Importantly this statistic also excludes the ongoing operational waste generated in all occupied buildings, and so is understated. Construction waste is made up of aggregates (concrete, stones, bricks) and soils, wood, metals, glass, biodegradable waste, plastic, insulation and gypsum based materials, paper and cardboard, a very high percentage of which are reusable or recyclable if separated at source.

2. Design

Architects and engineers have a very significant opportunity to affect the waste generated through the life cycle of a building by determining the method of construction and the materials specified. From simple strategies like utilizing building rubble onsite as fill for instance, or reusing items from demolished buildings such as wooden window frames, by specifying materials with recycled content, and adopting strategies and building methods geared to dismantling and designed for deconstruction – design affects everything, and with careful planning and consideration given to waste and reusing materials at concept stage, much waste to landfill can be avoided.
The construction industry is one of the largest and most significant industries, being at the same time the main consumer of natural resources and one of the largest polluters. Current construction practices of dumping the wastes in landfills allow for the depletion of natural resources and does not account for energy and material conservation. Wastes from the construction, remodeling, and repairing of individual residences, commercial buildings, and other structures are classified as construction wastes. The generation of construction waste can be attributed to the different phases of construction such as design, procurement and handling of materials as well as operation. Construction and demolition waste is considered one of the largest amounts of waste in the solid waste stream, and represents a real threat to all countries. Its composition is not unique and depends on the techniques of construction, type of building, country and many other factors. Factors of location and design make it intricate to accurately formulate a typical list of the components of construction waste arising for all construction projects worldwide. It is possible however, to identify a number of key components, which can be expected to occur to some extent in the waste stream in the majority of construction projects, such as:

1. Concrete
2. Wood
3. Metal ferrous (Steel)
4. Metal Non ferrous (Copper , Aluminum)
5. Masonry (bricks and mortar)
6. Plastic (PVC pipes, plastic films for packaging, wall coverings)
7. Glass
8. Ceramic Tiles
9. Insulation Material (mineral wool insulation, Styrofoam)
10. Drywall/gypsum board
11. Filling material (gravel, sand and soil)
12. Paper and Cardboard
13. Marble and granite

2.1 Construction waste

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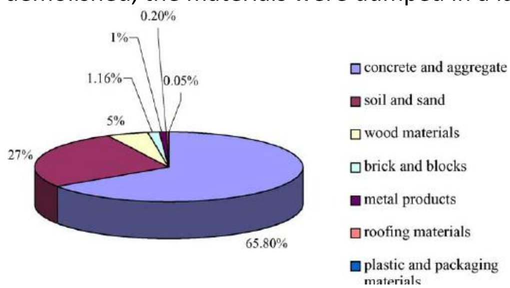

Fig 1- Pie diagram showing the percentage of construction wastes generated in a standard construction site

2.2 Learn to earn model (LEM)

Waste management and slum formation are two major problems worldwide; they can be seen as interrelated problems in the conventional sense that the more slums are formed, the more wastes are accumulated which raises the bar for reaching a solution to urbanization and waste management problems. On the contrary, in a modern thinking approach and as the world is focused around the Zero waste concept, waste can be seen as a wealth.

The Learn to Earn Model is considered as a human development model which helps the slum dwellers learn a skill by which they can generate income to sustain their daily living costs. It is designed to serve the community on the bigger scale by employing the slum dwellers on many activities which has positive social and economic impacts and promote sustainability. The main goal is to support the slum dwellers on the human development aspects as well as teaching them new skills. It helps in raising awareness of both men and women, providing training, workshops and other social activities according to their needs and condition in terms of age, physical ability and health condition in order to improve the slum dwellers level of education and skills to enhance their performance on the LEM approach.

2.3 Zero Waste and Closed Loop Thinking in the Construction Sector

There is a growing interest from architects in zero waste concepts. Cities and urban development are the areas where all concepts come together and can be embedded into practice into redesigning urban systems with zero waste and material flow in mind, by transforming the existing city and upgrading its recycling infrastructure in low-to-no carbon city districts. It‘s timely to rethink prefabrication and design for disassembly building resilience into urban systems. This will change the way we design, build and operate city districts in future (acknowledging that zero waste is much wider and complicated than expected at the first glance, and that we still have long distance from zero emission to zero waste in regard to the construction sector). For instance, façade systems made of composite materials create recycling and resource recovery problems. No debris should go to landfill, but instead, if allowable, may be used for leveling the site or may be as landscape elements. Concrete companies should use sustainable, recycled aggregates. Concrete was previously regarded as being difficult to be recycled, as closed-loop recycling for concrete structures is expensive. But concrete-related waste is now increasingly used as recycled aggregate (RA) for new concrete structures, and intensive research is carried out in Japan and China on new concrete recycling methods. The city district as a unit appears to be a good, effective scale. It means rejoining the urban with the rural community, therefore neighborhood and precinct planning must consider the climate crisis. For instance, planning better cities requires that composting facilities and recycling centers are in close proximity to avoid transporting materials over long distances. Reducing energy embodied in construction materials is an important strategy for mitigating our fossil-fuel dependency. Keeping the existing building stock is important, as the most sustainable building is always the one that already exists. Retrofitting existing districts is, therefore, essential.

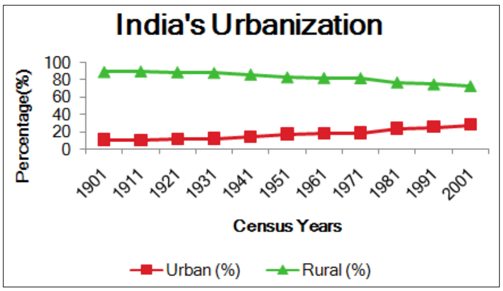

Fig. 2 – Rate of growth of population in urban & Rural India

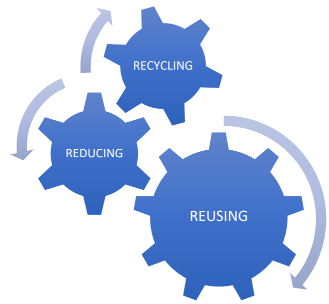

Fig. 3 – Concept of Reusing, Reducing and Recycling

3. Comparative study for cost analysis for conventional construction materials vs. construction using waste materials

Rajiv Awas Yojana is one of the latest schemes for the eradication of slums in which dwelling units are being constructed at present. As per a pilot DPR for slum housing in Guwahati, the total civil cost of one dwelling unit of carpet area 24.30 sqm using conventional materials is Rs 3,40,117.00. This excludes the cost of the earth-filling and excavation of the site, painting, electrical fixtures, plumbing fixtures, plinth protection works and periphery drains and anti termite treatment of the site. However, by alternative construction technology using waste materials, the same construction cost can be reduced to Rs 2,23,286,00 excluding the same items. Primary emphasis is given to the use of recyclable waste materials along with alternative construction materials.

Instead of conventional bricks of size 75mmx112mmx230mm which was proposed in the pilot DPR, alternative bricks made of fly ash and plastic waste in the ratio 30% fly ash and 50-60% plastic along with admixtures can be used to manufacture the bricks of the same size thereby reducing the cost by approximately 40-50% as per market survey analysis of the local market. Another advantage of the fly-ash plastic bricks is that it reduces the dead load of the structure and no plastering is needed to be done. By using recycled polythene sheets of 400 micron below the P.C.C. layer in the floor, the thickness of the P.C.C. layer as proposed in the pilot DPR can be reduced to half, thereby substantially reducing the construction cost and also using one of the key waste material – plastic.

Bamboo can be used as a reinforcing material on the slabs instead of steel. Though the stability of bamboo as reinforcement on the columns and beams is not recommended in the present, It can be easily done on the slabs, reducing the cost substantially. Old CGI sheets and bitumen drum sheets for the bitumen used in road construction can be used for the shuttering instead of plywood as proposed in the pilot DPR. Compressed bamboo and wood can be used instead of conventional wood as proposed in the pilot DPR. Although, there isn't much of a cost difference in both the materials, in the long run, it will be beneficial as it would mean less cutting of the trees and also the bamboo used for supporting the shuttering members can be treated, compressed and made into analysis of the materials with their cost analysis is given below

Table 2 - The comparative analysis of the conventional materials vs. Alternate Building materials using waste materials with their cost analysis

S.No	Item	Quantity	Unit	Total Cost (As per APWD SOR 2013-14) in Rupees	Bricks (in no. size 230x115x75mm)	Cement (Bags of 50 kg each)	Sand (in Cum)	Chips (in Cum)	Item (Alternate building material using waste materials)	Costing in Rupees
1	Brickwork	2.45	Cum	9538.29	1225	8	1.017	Nil	Flyash plastic bricks (30% flyash+50-60% plastic + admixtures)	3815.316
2	Brickwork	129.37	Sqm	50,872.93	7244.72	48	6.01459611	Nil	Flyash plastic bricks (30% flyash+50-60% plastic + admixtures)	20,349.17
3	PCC (1:3:6)	0.75	Cum	3199.7	Nil	4	0.342	0.684	400 micron recycled polythene sheets with concrete reducing the amount of of PCC thickenss by 50%	1599.85
4	PCC (1:4:8)	1.44	Cum	5620.83	Nil	5	0.673	1.35	400 micron recycled polythene sheets with concrete reducing the amount of of PCC thickenss by 50%	2810.415
5	Mortar (1:4)	0.57594096	Cum	Included in brickwork as per SOR	Nil	4	0.43195572	Nil	No alternate material to be used	1100
6	Plastering (1:4) (10 mm)	63.6	Sqm	7431.21	Nil	8	1.0176	Nil	No need to plaster for Flyash plastic bricks	0
7	Plastering (1:4) (15 mm)	337.26	Sqm	17736.05	Nil	51	6.74	Nil	No need to plaster for Flyash plastic bricks	0
8	Floor (1:2:4) 25 mm	15.98	Sqm	3699.36	Nil	2	1.14142857	2.2828571	No alternate material to be used	3699.36
9	Floor (1:3) 15 mm	5.86	Sqm	1350.9	Nil	1	0.065925	Nil	No alternate material to be used	1350.9
10	RCC (M20 grade) (1:1.5:3)	18.83	Cum	85741.95	Nil	99	5.13545455	10.270909	No alternate material to be used	85741.95
11	Reinforcements	22.17	Qntl	89756.62	Nil	Nil	Nil	Nil	Bamboo Cement concrete flooring slabs to be used which will reduce to costing by 60% to 75% depending upon the availability and transportation cost of bamboo	44878.31
12	Plywood Shuttering	163.84	Sqm	31475.1	Nil	Nil	Nil	Nil	Reusable CGI sheets and bitmen drum sheets can be used.	25000

13	Plywood Shuttering	7.41	R.M	753.83	Nil	Nil	Nil	Nil	Reusable CGI sheets and bitumen drum sheets can be used.	0
14	Wood	6.68	Sqm	21882.83	Nil	Nil	Nil	Nil	Compressed bamboo. Cost is more than wood, but it is more durable and eco-friendly and helps in reusing the bamboo which may be used in supporting the shuttering and scaffolding	21882.83
15	Glass (3mm thick)	3.32	Sqm	1613.89	Nil	Nil	Nil	Nil	No alternate material to be used	1613.89
16	Tiles	14.54	Sqm	9443.42	Nil	Nil	Nil	Nil	No alternate material to be used	9443.42
	Total Costing			**3,40,116.91**						**2,23,285.41**

4. Conclusion

Though many ways are available for the eradication or rather up-gradation of a slum, slum development using zero waste concept can help in the fulfillment of a dual purpose. Slums and waste disposal are two of the burning problems that is being faced by almost all modern civilizations. Using zero waste technology, the problem of disposal of wastes, especially the construction wastes is solved to certain extent. Also, construction through wastes reduces the construction cost by a substantial amount which in-turn helps in the construction of more number of dwelling unit against the allocated amount by a particular scheme. It can strengthen the Government policies on housing and slum up-gradation in multiple ways:

1) In meeting the housing supply in slums through a very low cost manner.
2) In handling the C& D waste.
3) In handling waste materials like plastic, which otherwise is a nightmare for waste disposal.
3) In preserving the resources of the country which in otherwise is used in the manufacturing of the construction materials.

With a proper understanding, methodology and analysis, a model can be proposed with alternate construction materials which shall be of recycled existing materials which are otherwise considered as wastes, and are mostly dumped in the dumpsites or landfill areas. Its feasibility will be tested and evaluated in order to assess its advantages and disadvantages and methods of viable implementation, which if successful, could be helpful to the slum upgradation process and also solving the problem of wastes to a great extent.

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