DETERMINATION OF COMPONENTS OF DEMOLITION WASTES FROM OLD STRUCTURES IN URBAN CITY (BENGALURU)

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Abstract

The objective of this paper is to device steps and implement it for old structures from the point of 4R's (Reduce, Recycle, Reuse and Recovery) for proper segregation and quantification of the different components of demolition waste. The steps are devised so as to segregate demolition waste at the site for reusing Brick and Mortar (B&M) and Recycle RCA i.e. Recycled Concrete Aggregate. The first part of the paper gives the introduction to the type of construction which has been adopted from about 30 to 40 years and the scenario now in Bengaluru, the reasons for it and why demolition are increasing which is giving rise to a lot of demolition waste. Hence based on the type of construction, the steps have been devised. The steps has been put in place to segregate the components into categories based on type of old structures in Bengaluru. After segregation the various components are to be quantified so that we get the quantity of each component of demolition. In the next part an attempt has been made to relate quantity to the size of the civil structure taking into consideration the standard sites and the built up areas which are being currently demolished). After quantifying, the type of components are identified and a study is made to define them with respect to the site size and built-up area.

Key Words: Demolition, Quantification, Segregation, Brick and Mortar, Recycled Concrete Aggregate.

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1. INTRODUCTION

Bengaluru is an Urban City and the centre for IT development in India. It is growing and developing faster than anybody could predict with the economic activity, population is booming which is leading to the replacement of old residential civil structures comprises of 3 major components:

1. Stone Foundation which has a depth of 4-8 feet.

2. Walls built of Red Bricks and plastered with mortar

3. Roofs made of reinforced concrete

And most of the structure being demolished are one + one building i.e. ground and first floor types as they were all individual residential structure housing a single small or large family. The sizes vary according to their financial status and the family requirements.

The development of the city is also coming with a large quantity of demolition waste, which is being dumped around the outskirts of the city. This is not only the problem of Bengaluru but also many cities in India and around the world. Keeping the broader scenario, environmental impact, global warming and 4R's perspectives, the investigation has been undertaken to set steps, segregate, quantify, identify and think on ways to put it to use, thus overcoming the ever increasing demolition waste problem.

2. METHODOLOGY

Fig. 2.1 Methodology for Demolition

The methodology consists of six segments which are in the sequence as shown in the flow chart. It is adopted to the demolition process of Civil Structures of the type that suits the structures construction in Bengaluru City for easy segregation so as to achieve the 4R's. The type of civil residential structures which are currently demolished are 40-50 years old. The constructed old structures basically has a strong stone Foundation, walls built of Red Bricks and plastered with mortar. The roof is reinforced concrete slabs. All old structures are two floored built in small, medium or big sites. The structures and sites depends on the economic status and the family requirements of the property owners. Now these structures are demolished for giving way for new structures which are always 4 storeyed to accommodate more families or for rental purposes.

2.1 DEMOLISH

Demolition means, bringing down the existing structure. There are various ways to demolish:

a. Manual

b. Manual plus Jack Hammers

c. Use of Hydraulic powered equipment (JCB)

Manual demolition is laborious and used to be applied before the invention of Jack Hammers which was carried out with sledge hammers.

Manual plus Jack Hammers is now usually the method for small as well as big structures. Commonly this method is used to first remove all the other parts of the construction like wooden doors, windows, wall cupboards (which are usually part of old structures of the type currently investigated). As all old structure of the type investigated (40-50 years) contain a lot of good doors and windows and a lot of wooden frames as in those days all houses had a lot of wooden works. In those days plastic doors and windows were virtually not known. All rooms like sitting, hall, bedrooms, kitchen, even bathrooms have good wooden doors, cupboards, etc. which are quite valuable.

Use of JCB's are not recommended as they sometimes cannot enter the small roads or they do the demolition from outside, hence cannot be used for systematic segregation as all the types of waste gets mixed or becomes a pile, from which extracting the different components of demolition is highly impossible and cumbersome.

Hence in this investigation keeping the 4R's as the driving factor. The second method i.e. manual plus Jack Hammers were chosen for the process of demolishing the investigated structures.

The Jack Hammers currently available vary from 1750 watts to 2500 watts. It can be operated manually. It has various attachments to do different operations. It is therefore convenient and only requires power cable to any location in the structure and the demolition can be executed in any specific steps we choose for maximum segregation and quantify the various components of demolition. The segregated components can be removed without the fear of mixing them up in steps so as to achieve the 4R's concept.

2.2 STEPS

The steps had been put in place so that it results in proper segregation and maximum recovery of each component of demolition. As already explained the first recoverable components were made of wood. The first step was obviously separation of the wooden accessories from the civil structure, next was to remove steel structure like gates, grills and any other roof items which are usually metals.

After removal of all the accessories the major components was roofs and walls. Both roofs and walls are different components of demolition. As roofs contain concrete and steel walls contain B&M

Now the roof is resting on the walls. But as the structure investigated were two storeyed, both roofs cannot be brought down together. Hence the first floor roof was removed first separated from steel reinforcements. RCA was removed before bringing down the walls of first floor. The first floor walls (B&M) was demolished and separated. In the next step the ground floor roof was removed, steel and RCA separated and cleared from the site. Finally the walls of the ground floor was demolished. At every step empty lorry weights was taken and the demolition component was loaded and again the lorry was weighed. The difference would give the weight of the demolition component. The same steps were done at all the four investigated sites.

2.3 SEGREGATE

1. Wooden and Steel Items
2. First Floor Roof - RCA and Steel
3. First Floor Wall - B&M
4. Ground Floor Roof - RCA and Steel
5. Ground Floor Walls - B&M
6. Left over Mixed Granular Material – SSG

The demolition process was intensely supervised to stick to the 4R's principles and maximum yield of each component of the civil structure. The segregation at each of the four sites are tabulated below. Here the total demolition waste is tabulated for all the four sites S1, S2, S3 and S4.

Table 1: Quantity of C&D Waste at Investigated Demolition Sites in kg

Quantified C&D Waste (in kg)					
Sl. No.	RCA	B&M	SSG	Others	Quantified C&D Wastes
S1	21,330	28,160	30,800	8,598	88,888
S2	40,480	58,660	60,444	18,194	1,77,778
S3	2,01,000	2,15,889	2,45,667	81,889	7,44,445
S4	1,79,800	1,67,400	2,10,800	62,000	6,20,000

2.4 QUANTIFY

After segregation the next step is to have a measure of waste against known or understandable engineering units (SI). Therefore two units have been used in this investigation to get an average value. The base is fixed on building area (m^2) of the civil structures. The waste is measured in kg. The built up areas were measured as accurate as possible with regular 50 m flexible tape as well as laser (digital) tools and recorded as tabulated below.

Table 2: Investigated Sites FAR

Sl. No.	Investigated Sites	Built Up in sqft	Built Up in m^2	FAR
1.	S1	1,800	167	1.50
2.	S2	4,000	372	1.67
3.	S3	18,000	1672	1.50
4.	S4	15,000	1394	2.00

Note: FAR is Floor Area Ratio which is 1.5 to 2.0 in Bengaluru City

Fig. 2.2 Demolition Site at MSRIT Hostel

2.5 IDENTIFIED COMPONENTS

Clearly as expected the components were (windows, doors, steel, etc.) which has been identified as others. This component was the first to be separated from the civil structures. This component invariably follows 4R's. As it is reused or sold in the market to be used again by slight alteration. Now this component is quite expensive as getting wood is becoming difficult as governments have restricted cutting down trees in the face of deforestation and global warming.

The second component is RCA from roofs which comprises of cement coated aggregates of sizes passing 53 mm sieve after recycling. But here it is in the form of concrete blocks separated from steel which is included in others. So roof material without steel is identified as RCA.

The third component is B&M from walls. This component is made up of bricks and mortar. The usual ratio of the two is 70:30. This is a major component of demolition waste.

2.6 RESULT

The result that is expected from this investigation is the components of demolition from the type of structure studied, their quantities in kg/m^3 and what steps to be adopted for proper and maximum segregation of the identified components. An attempt is made to establish a mathematical model for the type of structure investigated.

3. SELECTION OF DEMOLITION SITES

Four structures have been investigated in this study. The site of small, medium and large sizes has been chosen so that we get a fairly good average of the result.

The total area of the four structures are 1200 sqft (S1), 2400 sqft (S2), 12,000 sqft (S3) and 7500 sqft (S4). All are located in old urban areas of Bengaluru city (India), Karnataka State. S1 is located in Jayanagar, S2 is located in Indiranagar, S3 is located in Basavanagudi and S4 is located inside the MSRIT Campus. All sites (S1, S2, S3 and S4) investigated fall in the same construction type category (Stone Foundation, Brick & Mortar Wall and RCC Roof). All the structures are 40-50 years old. The above type of construction was prevalent in those days.

The sizes of the sites and built-up areas are tabulated as under.

Table 3: Investigated Sites Built-Up Area

Sl. No.	Site Dimensions in Square Feet	Built Up Area in Square Feet	Built Up Area in Square Metre
1.	30 X 40	1,800	167
2.	40 X 60	4,000	372
3.	100 X 120	18,000	1672
4.	50 X 150	15,000	1394

The location of the sites is in old developed urban areas of Bengaluru.

4. STEPS ADOPTED

Every step was planned keeping in mind proper and maximum segregation and minimum mixing of components. The steps were fixed or process was set by intensely studying at site (S1) and strict supervision on all the days of demolition from start to finish. After every category or each component was segregated immediately it was loaded and quantities recorded by weight (kg). By implementing the planned steps the result was four categories or components of demolition waste.

1. Others (Doors, Windows, Wood, Glass, Tiles, Steel, etc.)
2. RCA
3. B&M
4. SSG

The same strict supervision was implemented at other sites S2, S3 and S4.

Common Procedure followed for all Investigated Sites:

i. In the investigated sites, demolition was performed using power hammers and manual labour for smaller sites and JCB was used for Basavanagudi Bungalow and MSRIT Hostel.
ii. Windows and doors and other usable construction materials were removed first.
iii. 1st floor roof was demolished.
iv. RCA was separated from steel.
v. 1st floor walls were demolished.
vi. Ground floor roof was demolished.
vii. RCA was separated from steel.
viii. Ground floor walls were demolished.
ix. At each step measurements were made to quantify demolition waste and the built up area was recorded.

5. SEGREGATE

By strictly following the steps adopted at S1 and intense supervision at other sites i.e. S2, S3 and S4 resulted in proper identification of different components of demolition. The data collected is tabulated in the tables against each site and categories identified for proper analysis and quantification.

The identified components (i.e. Recycled Concrete Aggregate (RCA), Brick & Mortar (B&M), Soil, Sand and Gravel (SSG), Others) are segregated in the following tables for analysis.

Recycled Concrete Aggregate (RCA), Brick and Mortar (B&M), Soil Sand & Gravel (SSG) and Others (Doors, Windows, Wood, Glass, Tiles, Steel, etc.)

Site 1 investigated is located in Jayanagar whose dimensions are 30 feet by 40 feet, the structure is Ground + 1 whose Built-Up Area is 167 m^2.

Table 4: Demolition Components of Site 1 (S1)

Sl. No.	Components	Quantity in kg
1.	RCA	21,330
2.	B&M	28,160
3.	SSG	30,800
4.	Others	8,598

Site 2 investigated is located in Indiranagar whose dimensions are 40 feet by 60 feet, the structure is Ground + 1whose Built Up Area is 372 m^2.

Table 5: Demolition Components of Site 2 (S2)

Sl. No.	Components	Quantity in kg
1.	RCA	40,480
2.	B&M	58.660
3.	SSG	60,444
4.	Others	18,194

Site 3 investigated is located in Basavanagudi whose dimensions are 100 feet by 120 feet, the structure is Ground + 1 whose Built Up Area is 1672 m^2.

Table 6: Demolition Components of Site 3 (S3)

Sl. No.	Components	Quantity in kg
1.	RCA	2,01,000
2.	B&M	2,15,889
3.	SSG	2,45,667
4.	Others	81,889

Site 4 investigated is located in MSRIT Hostel whose dimensions are 50 feet by 150 feet, the structure is Ground + 1whose Built Up Area is 1394 m^2.

Table 7: Demolition Components of Site 4 (S4)

Sl. No.	Components	Quantity in kg
1.	RCA	1,79,800
2.	B&M	1,67,400
3.	SSG	2,10,800
4.	Others	62,000

6. QUANTIFICATION

In this part each category or component is taken separately from all the four sites and analysed to get the average of each component per square meter built up area. The data is processed graphically and statistically as shown below to get the component factor in kg/m² so that the factor can be used for any other similar civil structure demolition anywhere else (generalised).

Analysis of Recycled Concrete Aggregate (RCA) at all 4 Investigated sites.

Table 8: RCA Values at all 4 Investigated Sites

Sl. No.	Site	RCA in kg	Built Up Area in m²	Quantity in kg/m²
1.	S1	21330	167	127
2.	S2	40480	372	108
3.	S3	201000	1672	120
4.	S4	179800	1394	128

The graph below has the built up area on the left y-axis is m². The right side y-axis has quantity of RCA/m² of built up area. The x-axis indicates the sites which are four in number. The scale for built up area varies from zero to 1800 m². The quantity of RCA/m² scale varies from 95 kg/m² to 130 kg/m². The graph is a consolidated figure which gives the variation and values of RCA at all the four sites.

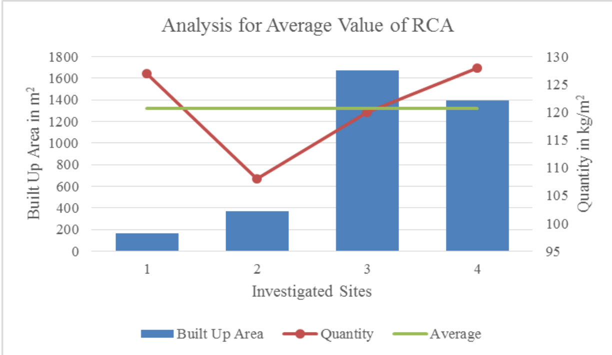

Fig. 6.1 Analysis for Average Value of RCA

$$\text{Average} = \frac{127+108+120+128}{4}$$

$$\frac{483}{4} = 120.7 \text{ kg/m}^2 \approx 121 \text{ kg/m}^2$$

The quantity of RCA varies from 108 kg/m² to 128 kg/m², the minimum being 108 kg/m² for site two and the maximum 128 kg/m² for site four. The average value of all the four sites stands at 121 kg/m². The bar graphs indicate the built up areas in m². The line graph superimposed on it indicates the quantity of RCA per m² which can be read from the right hand side of the graph. The straight line parallel to the x-axis indicates the average value of 121 kg/m².

Analysis of Brick & Mortar (B&M) at all 4 Investigated sites.

Table 9: B&M Values at all 4 Investigated Sites

Sl. No.	Site	B&M in kg	Built Up Area in m²	Quantity in kg/m²
1.	S1	28160	167	168
2.	S2	58660	372	157
3.	S3	215889	1672	129
4.	S4	167400	1394	120

The graph below has the built up area on the left y-axis is m². The right side y-axis has quantity of B&M/m² of built up area. The x-axis indicates the sites which are four in number. The scale for built up area varies from zero to 1800 m². The quantity of B&M/m² scale varies from 0 kg/m² to 180 kg/m². The graph is a consolidated figure which gives the variation and values of B&M at all the four sites.

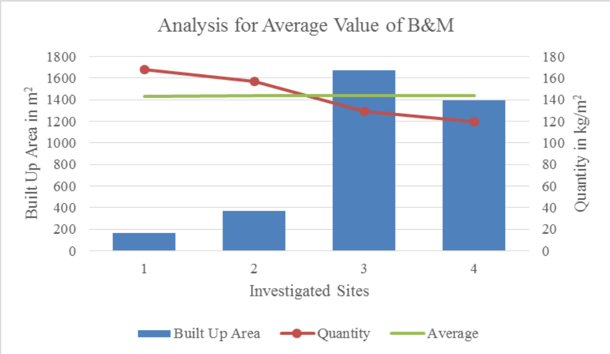

Fig. 6.2 Analysis for Average Value of B&M

$$\text{Average} = \frac{168+157+129+120}{4}$$

$$\frac{574}{4} = 143.5\ \text{kg/m}^2 \approx 144\ \text{kg/m}^2$$

The quantity of B&M varies from 120 kg/m² to 168 kg/m², the minimum being 120 kg/m² for site four and the maximum 168 kg/m² for site one. The average value of all the four sites stands at 144 kg/m². The bar graphs indicate the built up areas in m². The line graph superimposed on it indicates the quantity of B&M per m² which can be read from the right hand side of the graph. The straight line parallel to the x-axis indicates the average value of 144 kg/m².

Analysis of Soil, Sand and Gravel (SSG) at all 4 Investigated sites.

Table 10: SSG Values at all 4 Investigated Sites

Sl. No.	Site	SSG in kg	Built Up Area in m²	Quantity in kg/m²
1.	S1	30800	167	184
2.	S2	60444	372	162
3.	S3	245667	1672	147
4.	S4	210800	1394	151

The graph below has the built up area on the left y-axis is m². The right side y-axis has quantity of SSG/m² of built up area. The x-axis indicates the sites which are four in number. The scale for built up area varies from zero to 3,00,000 m². The quantity of SSG/m² scale varies from 0 kg/m² to 200 kg/m². The graph is a consolidated figure which gives the variation and values of SSG at all the four sites.

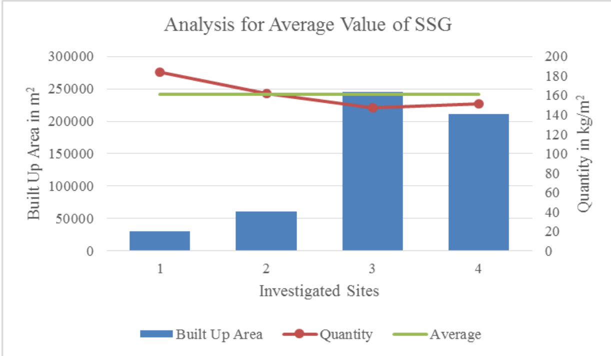

Fig. 6.3 Analysis for Average Value of SSG

$$\text{Average} = \frac{184+162+147+151}{4}$$

$$\frac{644}{4} = 161\ \text{kg/m}^2$$

The quantity of SSG varies from 147 kg/m² to 184 kg/m², the minimum being 147 kg/m² for site three and the maximum 184 kg/m² for site one. The average value of all the four sites stands at 161 kg/m². The bar graphs indicate the built up areas in m². The line graph superimposed on it indicates the quantity of SSG per m² which can be read from the right hand side of the graph. The straight line parallel to the x-axis indicates the average value of 161 kg/m².

Analysis of Others (Doors, Windows, Wood, Glass, Tiles, etc.) at all 4 Investigated sites.

Table 11: Others Values at all 4 Investigated Sites

Sl. No.	Site	Others in kg	Built Up Area in m²	Quantity in kg/m²
1.	S1	8598	167	51
2.	S2	18194	372	49
3.	S3	81889	1672	49
4.	S4	62000	1394	45

The graph below has the built up area on the left y-axis is m². The right side y-axis has quantity of Others/m² of built up area. The x-axis indicates the sites which are four in number. The scale for built up area varies from zero to 1,800 m². The quantity of Others/m² scale varies from 42 kg/m² to 52 kg/m². The graph is a consolidated figure which gives the variation and values of Others at all the four sites.

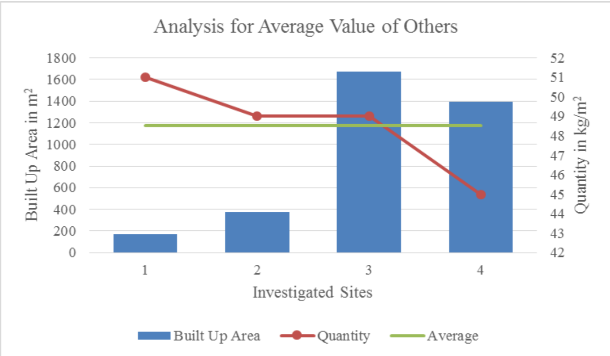

Fig. 6.4 Analysis for Average Value of Others

$$\text{Average} = \frac{51+49+49+45}{4}$$

$$\frac{194}{4} = 49 \text{ kg/m}^2$$

The quantity of Others varies from 45 kg/m² to 51 kg/m², the minimum being 45 kg/m² for site four and the maximum 51 kg/m² for site one. The average value of all the four sites stands at 49 kg/m². The bar graphs indicate the built up areas in m². The line graph superimposed on it indicates the quantity of Others per m² which can be read from the right hand side of the graph. The straight line parallel to the x-axis indicates the average value of 49 kg/m².

RCA generated is 121 kg/m²

B&M generated is 144 kg/m²

SSG generated is 161 kg/m²

Others generated is 49 kg/m²

Identified Components

The Identified Components of the old structures in Bengaluru City are:

1. Recycled Concrete Aggregate (RCA)
2. Brick and Mortar (B&M)
3. Soil, Sand and Gravel (SSG)
4. Others (Doors, Windows, Wood, Glass, Tiles, Steel, etc.)

7. RESULTS AND ANALYSIS

1. RCA comprises of coarse and fine aggregates of sizes less than or 100% passing IS 53 mm sieve.
2. Brick and Mortar comprises of bricks and attached mortar to them.
3. SSG is a mix of sand, soil and gravel which is left back after RCA and B&M are removed from the investigated sites.
4. Others include Wood, Tiles, Metal, Glass, etc.
5. a. The analysis has shown that 121 kg/m² of RCA are the average quantities generated from the type of structures selected for Investigation.

b. The analysis has shown that 144 kg/m² of B&M are the average quantities generated from the type of structures selected for Investigation.

c. The analysis has shown that 161 kg/m² of SSG are the average quantities generated from the type of structures selected for Investigation.

d. The analysis has shown that 49 kg/m² of Others are the average quantities generated from the type of structures selected for Investigation.

The study at the demolition sites has resulted in factors after analysis. These factors can be used to estimate and quantify the different types of demolition wastes of any small, medium and large residential sites, if the total built up area is measured and multiplied by the factors from Table 12

Table 12: Demolition Components and its Factors

Sl. No.	Material	Factors (F_n)	Factor Values
1.	RCA	F_1	121
2.	B&M	F_2	144
3.	SSG	F_3	161
4.	Others	F_4	48

$$\text{Total Demolition Waste in kg} = \sum_{n=1}^{4} (\boldsymbol{BA})\boldsymbol{Fn}$$

where,

n = 1 to 4

BA = Built – Up Area in m^2

Fn = Factor Values in kg/m^2 from the above Table

8. CONCLUSIONS

1. The methodology adopted for demolition has proved that it was systematic and useful in fairly good segregation.

2. The demolition waste is segregated into 4 categories:

i. RCA
ii. B&M
iii. SSG
iv. Others (Doors, Windows, Wood, Glass, Tiles, Steel, etc.)

3. Keeping aside the others (wooden windows, doors, etc.) we can say the total of recyclable materials are RCA, B&M and SSG.

$$RCA + B\&M + SSG = 121+144+161 = 426\ kg/m^2$$

$$\%\ RCA = \frac{121}{426} X\ 100 = 28.40\ \%$$

$$\%\ B\&M = \frac{144}{426} X\ 100 = 33.80\ \%$$

$$\%\ SSG = \frac{161}{426} X\ 100 = 37.80\ \%$$

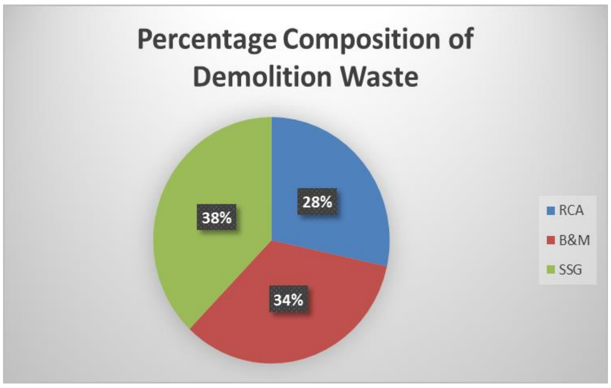

Fig. 8.1 Percentage Composition of Demolition Waste

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