RECOVERY AND REUSE OF FINE AGGREGATE FROM DEBRIS OF BUILDING DEMOLITION

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ABSTRACT

Demolition of unsafe buildings and structures requiring extensive modifications is more common now a days. Almost 30% of new constructions are coming up on the demolition site. Handling of demolition debris has become a challenging issue in all the developing countries including India. The growth rate in the construction sector is 1.5 times in 5 years. While the demand for aggregates is increasing day-by-day, the natural resources like sand, gravel etc. are decreasing around the world. The need for the recycle of aggregate recovered from the debris is the need of the hour to meet the rising demand. Various studies have been reported on the subject. The present study reports the developed empirical relations between the area of the building and different items of materials in the debris for the estimation of quantity generation. Experimental results on the strength of concrete for different proportions of replacement of fine aggregate recovered from the debris are presented. The study results encourage the use of fine aggregate recycle in concrete.

Keywords : Construction & Demolition, Debris, Fine Aggregate, Coarse Aggregate, Sieve Analysis, Compressive Strength, Split Tensile Strength.

1. INTRODUCTION

The infrastructure development is taking place in a rapid manner in India. . Concrete structures are much loved due to its longer life and easy maintenance. The conventional concrete is produced by using natural sand which is obtained from the river beds. Many new constructions, nearly 30%, are taking place at the demolished sites. Building demolition debris results as solid waste and it solicits environmental concern. A scene of debris stacked on road side is depicted in figure 1. It has been reported that 23.75million tons of demolition wastes are generated annually in India [1]. As the fine aggregate requirement for the construction increases day by day, the need for finding out the alternate source is realized (natural sources of sand is getting depleted every day). Government is also restricting the sand quarrying in the river bed so as to maintain the ecology and environment.

Various researches have been done to identify some alternative materials like quarry dust, fly ash, blast furnace slag, lime stone powder, granite powder, etc for use in concrete [2-11]. The partial replacement of sand in concrete by PET bottles has been studied [12]. Use of artificial sand, manufactured sand, crushed rock fines etc., as fine aggregate in concrete has been evaluated [13-16]. Recycle of recovered material from the demolition debris as fine aggregate has been investigated by various researchers [17-29]. The recycled fine obtained from demolished concrete slab possessed negligible value of lime reactivity and the same can be utilized as fine aggregate in making concrete [30]. Though the studies report the possible use of above materials in concrete, it is yet to come into practice widely. Moreover, the literature on the quantity estimate of demolition debris generation is scanty.

With the above factors in mind, the present work has been done with the following objectives:

- Assessment of the debris generation in building demolition acitivity, (Kg per square metre of floor area)
- Economics of building demolition (expense and income on selling doors, windows etc),
- Characterisation of debris (sieve analysis),
- Experimental studies on strength assessment (Cubes test) with partial and full replacement of sand with recovered fine aggregate from debris, and
- Exploration of reuse of debris in brick and slab casting.

Figure 1. A heap of C & D Debris on the road side

2. METHODOLOGY

2.1 Survey on debris quantification and cost

The technique of direct observation with simple questionnaire was used to collect the information on the quantities of debris generated. Information on the number of trips and the size of truck were also gathered. Besides concrete and brick related quantity, details of steel and wood were obtained. The expenditure for demolition and cost recovery from the sale of wood and steel were also assessed. The above data were collected from Anuppanadi, K.K Nagar, Anna Nagar and Iyer Bangalow in Madurai, R.M.Colony in Dinidgul and Kajamalai in Trichy, India..

2.2 Sieve analysis

Building demolition debris was collected in a gunny bag for the characterization. Debris collection is shown in Figure 2.

Figure 2. Collection of debris.

Sieve analysis was done employing Indian Standard test Sieve. In this test, 63mm, 40mm, 20mm, 16mm, 10mm, 4.75mm, 2.36mm, 1.00mm, 60μ and 7.50 μ sieves were placed in order. Sieve analysis was performed by using Gyratory Sieve Shaker (Figure 3). Fineness Modulus was also determined for grading.

Figure 3. Photo showing Sieve analysis.

2.3 Cube Compressive Strength.

Concrete cubes of size 150mm x 150mm x 150mm were cast with the various proportions of aggregate as given in table 1.

Table 1: Various proportions of replacement of FA.

Cube	**Fine Aggregate**		**Course Aggregate**	
	Debris	**Natural Sand**	**Debris**	**Natural Aggregate**
I	25 %	75 %	---	100 %
II	50 %	50 %	---	100 %
III	100 %	---	---	100 %
IV	100 %	---	100 %	---
Standard	---	100 %	---	100 %
Solid Block	Cement Mortar 1:6		100 %	---
Slab	Cement Mortar 1:6		100 %	---

M15 grade concrete was prepared using the above mix proportions with Ordinary Portland cement of 43 Grade. Water Cement Ratio was taken as 0.50. Four sets of cube were prepared and the average compressive strength was taken after 28 days curing. For comparison, a standard cubes were also prepared.

2.4 Making of solid Slab & Pavement Slab

For making solid block and pavement slab, cement mortar of mix 1:6 (One part of cement and six parts of fine aggregate recovered from debris) was used. The solid block and pavement slab were cured for 28 days. Compressive strength of the solid block and were taken and recorded.

3. RESULTS & DISCUSSION

3.0 Debris generation

3.1 Total Debris Generation

Total quantity of debris generated at six locations with the area of the building is tabulated (Table 2). It is observed from the table that the Quantity of debris increases with increasing area. Generally, the quantity of various items of materials required for the construction will increase with the plinth area. So, is the trend of increasing debris with the area of the building.

A correlation between the plinth area of the demolished building and the total quantity of debris was performed. Very good correlation, almost equal to unity, is obtained. The obtained linear equation is given below (Equation 1).

$$Y = 2.052 * X - 17.40 \quad \text{------------------------------------} \quad (1)$$

Where, Y = Total quantity of debris in m^3 and

X = Area of the building in m^2

Table 2. Total quantity of debris with area of the building

Sl. No	Location	Area of Building		Total Debris	
		Sq.ft	m^2	Truck load	m^3
1	Anuppanadi, Madurai	357	33.17	11	62.30
2	R.M Colony, Dindigul	735	68.28	20	113.27
3	K.K Nagar, Madurai	819	76.09	23	130.26
4	Kajamalai, Trichy	1,014	94.20	31	175.56
5	Iyer Bungalow, Madurai	1,170	108.70	36	203.88
6	Anna Nagar, Madurai	1,443	134.06	47	266.18

3.2 Quantity of Concrete debris generated

The quantity of debris exclusively resulting from RCC members with the area of the building is given in Figure 4. It indicates that the concrete quantity increases with the area of the building. The quantity of concrete debris resulting from RCC members as a direct relationship with the area is shown in equation 2.

$$Y = 0.039 * X - 0.177 \quad \text{---} \quad (2)$$

Where, Y = Quantity of RCC Debris in m^3 and

X = Area of the building in m^2

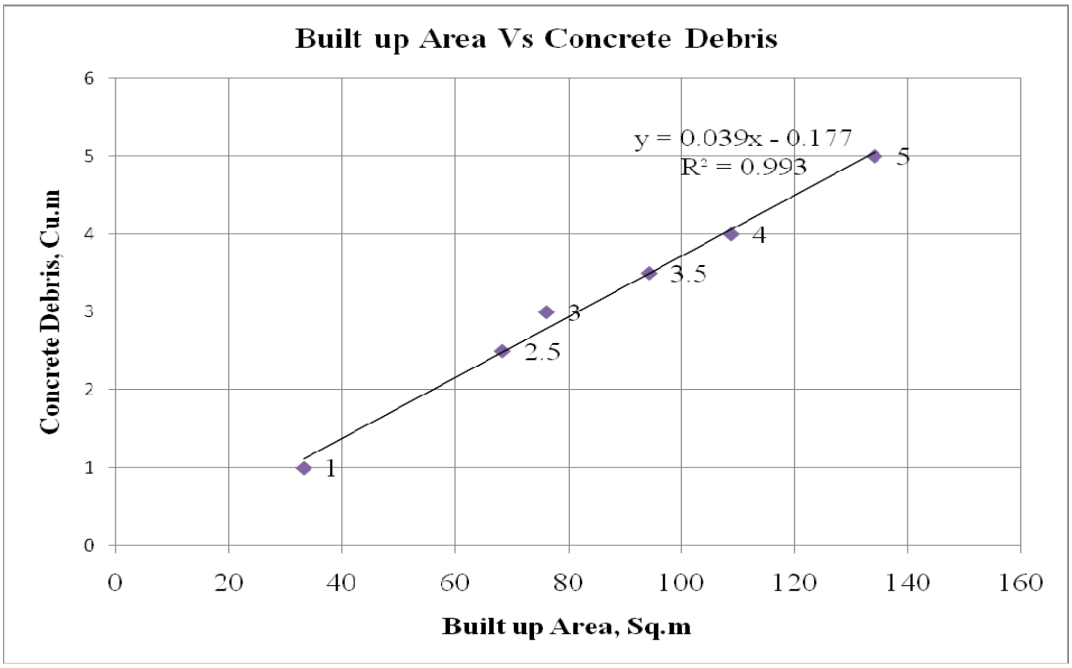


Figure 4. Built up Area Vs Concrete Debris.

3.3 Quantity of retrieved Steel

The quantity of steel recovered from the reinforcements with the area of the building is given in table 3. The quantity of steel generated as debris is also having similar pattern as the RCC has. The relationship between steel and area given in the equation 3.

Normally the reinforcement at 10 kg per m^2 is provided for RCC members. The retrieved steel quantity is about 8 kg per m^2. The difference in quantity, 2 kg per m^2 may be lost as sticking to the concrete.

$Y = 7.739 * X + 19.87$ -- (3)

Where, Y = Quantity of retrieved Steel in Kg & X = Area of the building in m^2

Table 3. Quantity of Steel recovered.

Sl. No	Location	Area of Building		Retrieved Steel
		Sq.ft	m^2	Kg
1	Anuppanadi, Madurai	357	33.17	266
2	R.M Colony, Dindigul	735	68.28	545
3	K.K Nagar, Madurai	819	76.09	610
4	Kajamalai, Trichy	1,014	94.20	780
5	Iyer Bungalow, Madurai	1,170	108.70	860
6	Anna Nagar, Madurai	1,443	134.06	1040

3.4 Quantity of Wood recovered

The wooden members such as doors, windows and ventilators are commonly dismantled as a first step of demolition. The quantity of wood recovered with the area of the building is given in figure 5. The relationship between wood and area given in the equation 4.

$Y = 0.008 * X – 0.009$ -- (4)

Where, Y = Quantity of wood in m^3 & X = Area of the building in m^2

A graph was plotted relating with the plinth area of the demolished building and the quantity of retrieved wood shown in figure 5.

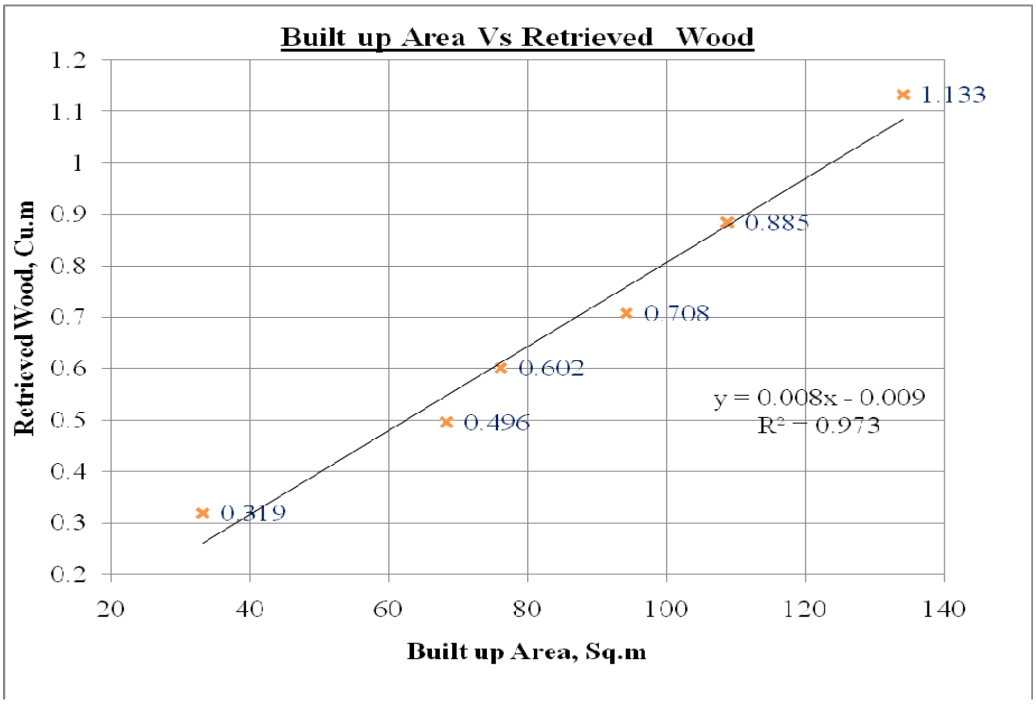


Figure 5. Built up Area Vs Retrieved Wood

3.5 Quantity of Brick & Other debris generated

The quantity of debris remaining other than RCC members with the area of the building is given in Table 4. The quantity of brick and other debris has a direct relationship with the area is shown in equation in 5.

$$Y = 1.831 * X - 16.40 \quad (5)$$

Where, Y = Quantity of Brick and other Debris in m^3

X = Area of the building in m^2

Table 4. Quantity of Brick & Other Debris

Sl. No	Location	Area of Building		Brick & other Debris	
		Sq.ft	m^2	Truck load	m^3
1	Anuppanadi, Madurai	357	33.17	10	56.63
2	R.M Colony, Dindigul	735	68.28	17.5	99.11
3	K.K Nagar, Madurai	819	76.09	20	113.27
4	Kajamalai, Trichy	1,014	94.20	27.5	155.74
5	Iyer Bungalow, Madurai	1,170	108.70	32	181.23
6	Anna Nagar, Madurai	1,443	134.06	42	237.86

3.6 Expenditure incurred for Demolition

The data related to the total expenditure incurred for the demolition of the building with respect to area of the building is shown in figure 6. The expenditure increases with the area. The average rate per unit area is Rs.208. The expenditure incurred for the demolition has a direct relationship with the area is shown in equation 6.

$$Y = 168.0 * X + 2785 \quad (6)$$

Where, Y = Expenditure incurred for demolition in Rs.

X = Area of the building in m^2

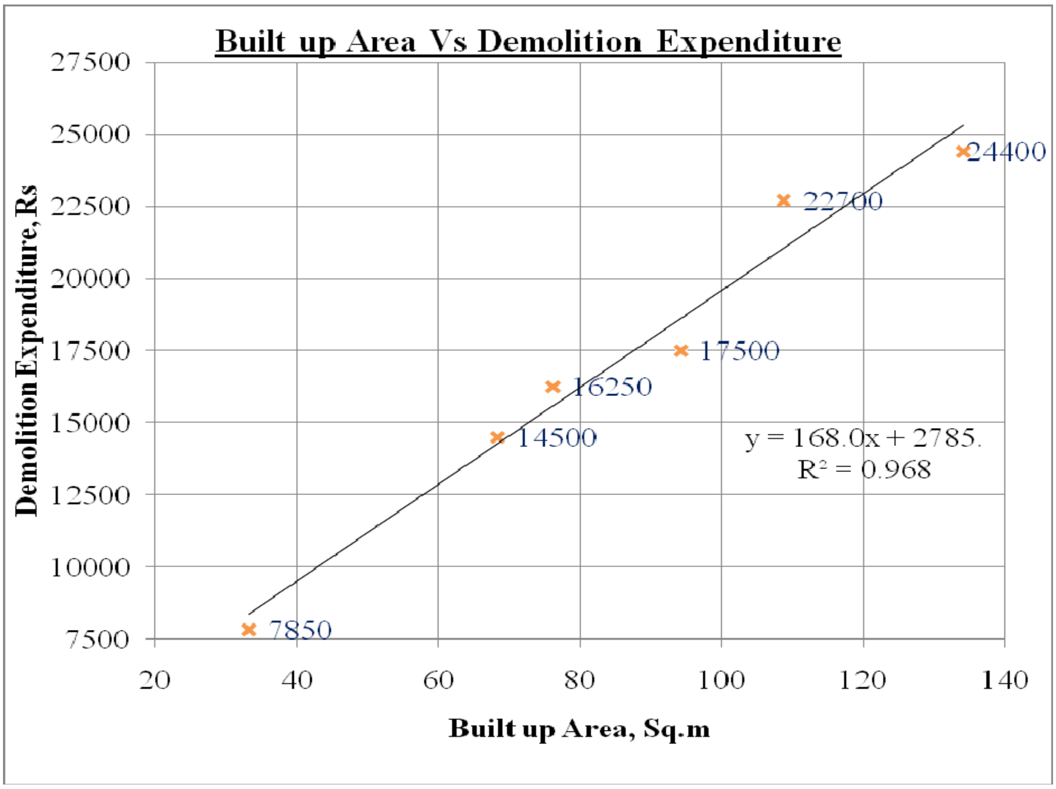


Figure 6. Built up Area Vs Demolition Expenditure.

3.7 Sale of debris.

The total income on the sale of debris with the area of the building is given in table 5. The income on the sale of debris has a direct relationship with the area is shown in equation in 7.

$$Y = 264.5 * X + 639.50 \quad \text{--} \quad (7)$$

Where, Y = Income on the sale of Debris in Rs.

X = Area of the building in m^2

Table 5. Income from Demolition.

Sl. No	Location	Area of Building		Income from Demolition
		Sq.ft	m^2	Rs.
1	Anuppanadi, Madurai	357	33.17	9,850
2	R.M Colony, Dindigul	735	68.28	18,000
3	K.K Nagar, Madurai	819	76.09	20,600
4	Kajamalai, Trichy	1,014	94.20	25,800
5	Iyer Bungalow, Madurai	1,170	108.70	29,500
6	Anna Nagar, Madurai	1,443	134.06	36,200

3.8 Comparison between Expenditure and Income.

The cost involved in the demolition of building with the value of recovered material is tabulated in Table 6. It is observed that the revenue resulting from selling of recovered materials very well meets the demolition expense.

Table 6. Comparison between Expenditure and Income.

Sl. No	Location	Area of Building		Demolition Expenditure	Income from Demolition Rs.
		Sq.ft	m^2	Rs.	
1	Anuppanadi, Madurai	357	33.17	7,850	9,850
2	R.M Colony, Dindigul	735	68.28	14,500	18,000
3	K.K Nagar, Madurai	819	76.09	16,250	20,600
4	Kajamalai, Trichy	1,014	94.20	17,500	25,800
5	Iyer Bungalow, Madurai	1,170	108.70	22,700	29,500
6	Anna Nagar, Madurai	1,443	134.06	24,400	36,200

3.9 Sieve Analysis.

Sieve analysis indicates the various sizes of particles present. Material passing 10 mm screen and retained in 75 micron sieve is generally classified as fine aggregate. Out of the total quantity of debris generated, 28.81 % is of fine aggregate (FA). The rest falls in the size ranging from 16mm to 63mm. 40mm size particles share 20% while the 20mm size volume is 30%. For plain cement concrete (PCC), 40 mm can be used. Similarly, 20mm size may also find application in RCC (reinforced cement concrete) and PCC.

The particle size distribution is shown in table 7. Fineness Modulus value was found to be 3.87 which is slightly higher than the limit stipulated by IS. The sieve analysis indicates that nearly 30% of quantity (Fine Aggregate) confirms with the Grading Zone I of IS 383 – 1970 (Table 8).

Table 7. Sieve analysis Result.

Sieve Designation	Wt. with Pan (kg)	Wt. of sample retained (kg)	% Retained	% Passing	Remarks
63 mm	1.396	0.228	7.58	92.42	
40 mm	1.811	0.643	21.39	71.03	20 %
20 mm	2.057	0.889	29.57	41.46	30 %
16 mm	1.300	0.132	4.39	37.07	
10 mm	1.417	0.249	8.28	28.79	
4.75 mm	1.357	0.189	6.29	22.50	Can be used as FA (28.81%)
2.36 mm	1.248	0.080	2.66	19.84	
1.00 mm	1.302	0.134	4.46	15.38	
600 micron	1.527	0.359	11.94	3.44	
75 micron	1.268	0.100	3.33	0.11	
Less than 75u	1.172	0.004	0.13	0.00	

Table 8. Identifying the Grading Zone.

Sieve Designation	Wt. with Pan (Kg)	Wt. without Pan (Kg)	% of Material Retained	Cumulative % of Material retained	% of Passing	Limit (IS 383 – 1970)	Remarks
10 mm	1.168	0.000	0.00	0.00	100	100	Confirms nearly to Grading Zone I
4.75 mm	1.357	0.189	21.82	21.82	78.18	90 – 100	
2.36 mm	1.248	0.080	9.24	31.06	68.94	60 – 95	
1.00 mm	1.302	0.134	15.47	46.53	53.47	30 – 70	
600 micron	1.527	0.359	41.45	87.98	12.02	15 – 34	FM = 3.87
75 micron	1.268	0.100	11.55	99.53	0.11	0 – 10	Limit = 2.20 to 3.20
Less than 75micron	1.172	0.004	0.47	100.00	0.00		
Total		**0.866**	**100.00**	**386.92**			

3.10 Cube Test.

28 days cube compressive strength for various proportion of recovered fine aggregate (FA) from the debris is exhibited in Table 9. It is observed from the table that the cubes prepared with various proportions show the strength more than 15 KN/m^2, the standard value of M15 mix. It indicates clearly that the recovered FA can be substituted for sand. Moreover, the compressive strength of solid block and pavement slab prepared using recovered FA recommends for such applications.

Table 9. Cube compressive Strength.

Cube	Fine Aggregate		Course Aggregate		Weight Kg	Peak Load 'KN'	Average Compressive Strength in 28 days 'KN/m^2'
	Debris	Natural Sand	Debris	Natural Aggregate			
I	25 %	75 %	---	100 %	8.360	369.30	16.41
II	50 %	50 %	---	100 %	8.420	361.10	16.05
III	100 %	---	---	100 %	7.960	356.60	15.85
IV	100 %	---	100 %	---	7.440	340.90	15.15
Standard	---	100 %	---	100 %	8.650	394.20	17.52
Solid Block	100 %	---	100 %	---	4.680	74.80	3.40
Slab	100 %	---	100 %	---	6.040	387.60	9.27

3.11 Split Tensile Strength.

Output of the split Tensile Strength is tabulated in Table 10.

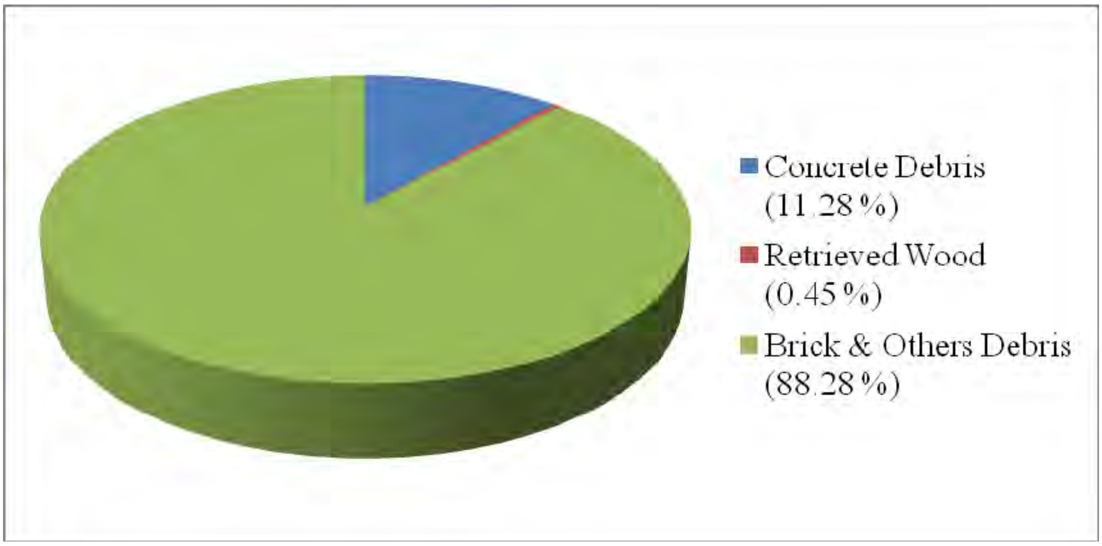
Table 10. Split Tensile Strength Test Results.

Cube	Fine Aggregate		Course Aggregate		Weight	Split Tensile Strength in 28 days
	Debris	Natural Sand	Debris	Natural Aggregate	Kg	'N/mm^2'
I	25 %	75 %	---	100 %	8.360	2.03
II	50 %	50 %	---	100 %	8.420	1.99
III	100 %	---	---	100 %	7.960	1.92
IV	100 %	---	100 %	---	7.440	1.88
Standard	---	100 %	---	100 %	8.650	2.10
Solid Block	100 %	---	100 %	---	4.680	---
Slab	100 %	---	100 %	---	6.040	---

4. SUMMARY & CONCLUSION

The following conclusions are drawn:

- ✓ The constituents in the building demolition debris is shown as Pie chart. Of the total quantity of debris, Concrete constitute 11.28 %, wood take the share 0.45% and the balance is brick and others.



- ✓ The following empirical equations may be useful in estimating the quantity of each item. This will be helpful to the Planners and Engineers for quick assessment during planning and reuse purposes.

Sl. No	Description	Equation
1	Total debris	Y = 2.052 * X – 17.40
2	Concrete debris	Y = 0.039 * X – 0.177
3	Retrieved Steel	Y = 7.739 * X – 19.87
4	Retrieved wood	Y = 0.008 * X – 0.009
5	Brick & Other Debris	Y = 1.831 * X – 16.40
6	Demolition Expenditure	Y = 168.0 * X + 2,785
7	Income from Demolition	Y = 264.5 * X + 639.5

- ✓ The particle sizes of debris vary from 75micron to 63mm. Nearly 30% of the quantity falls under Zone I of IS 383 – 1970 which may be used as fine aggregate in place of natural sand. And 40 mm size accounts for almost 20% which may find its application in PCC. 20 mm particle size (Coarse aggregate) is about 30% of total volume.
- ✓ The cube compressive strength of M15 mix prepared with various proportions of replacement of sand with recovered FA is observed to be more than $15N/mm^2$. Hence, the recovered FA from the debris may be considered as good alternate in concreting.

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