Optimization of Concrete and Brick waste by reusing them in Pavers

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Abstract : The construction and demolition waste constitutes of a major percentage of the waste generated in cities and is an environmental threat also. Thorough literature study was conducted to identify the waste components in construction industry and it was identified that concrete and brick waste are found majorly in construction and demolition waste. This study has been undertaken to investigate the scope of reusing the concrete and brick waste in pavers. The waste material was collected from construction sites and converted to reusable form. Concrete is used as aggregate confirming to sieve analysis of 20mm size and brick waste was employed in the powder form as cement replacement. Experimental tests were conducted and it was found that the combination of replacement of 5% brick waste as fine aggregate and 10% concrete waste as coarse aggregate, achieved maximum strength of 27 N/mm^2 at 28^{th} day. The results concluded from the cost analysis verify that the replacement (of cement and aggregate) in the paver block reduce the cost of paver by Rs.2507 per 100 meter run.

Index Terms **- Construction and demolition waste, Reuse, optimization, cost analysis.**

I. INTRODUCTION

The construction industry is largest economy generating sector in India after agriculture. At the same time it generated huge construction and demolition waste which is creating environmental problems because of its mismanagement. Various environmental issues such as increase in the flood levels due to the illegal dumping of construction and demolition waste into the rivers, resource depletion, shortage of landfill and illegal dumping on hill slopes are evident in the metro cities, which are a result of mismanagement of this waste (Gayakwad, 2015). There is an urgent need to address this issue and search for ways of reutilizing this waste. Researchers proposed conceptual C&D waste management framework to maximize the 3R (Reduce, Reuse and Recycle) and minimise the disposal of construction waste. This approach can be used to make decisions related to selection of material, sorting, recycle/reuse and treatment or disposal options for C&D waste (Yeheyis, Hewage, Alam et al. 2013). The major components of construction and demolition waste are to be identified and strategies for their reuse are to be worked out to optimize the waste.

II. NEED OF STUDY

Construction industry is largest economic expenditure in India. According to eleventh five- year plan, it is the second largest economic activity after agriculture. The impact caused to the environment by Indian construction industry is also large. Construction industry consumes high volume of raw materials and products. It generates high employment opportunity. Based on an analysis of the forward and backward linkages of construction, the effect in the construction on economy is estimated to be significant (Thomas & Wilson, 2013). Due to the increase in the economic growth after development and redevelopment projects in the country subsequent increase in the urbanization in the cities as made construction sector to increase drastically, but also environmental impacts from construction and demolition (C & D) waste are increasingly becoming a major issue in urban solid waste management. Waste from individual house construction or demolition (Raju Ponnada, 2015)

- Find its way into nearby municipal bin/vat/waste storage depots, making the municipal waste heavy
- Degrade quality of municipal waste and makes it difficult for further treatment like composting.
- About 10-20 % finds its way into surface drains, choking them.

The construction industry is facing many challenges and one of the biggest challenges is management of construction and demolition waste from sites. There is an emergent need to minimize the wastage and find solutions for optimization of these resources.

III. METHODOLOGY

The study includes study of secondary data available for optimization of waste in construction industry. The waste material was then collected and experiments performed in the lab to test their suitability for replacement. Finally the calculations are carried out to study the significance of reuse of waste in terms of financial savings. The research methodology adopted for this study can be concluded in the following stages:

- Study of the existing literature available on C & D waste.

- Identification of two materials (brick & concrete) waste from C & D waste for further optimization study.
- Perform experimental tests after reusing these waste materials as block pavers (using different compositions) and find out their reusability probability as block pavers.
- Performing cost analysis to identify the benefits of reusing the waste.

IV. LITERATURE REVIEW

The composition of construction waste depends on the type of structure. For example, if the structure is flyover or bridge structures the composition will be usually concrete and steel. On the other hand, if the residential structures are built or demolished the composition will be in verity, it consists of concrete, steel, wood, tiles, paints, plastics etc. (Gayakwad, 2015)

All over the world, the growth of construction industry is enormous in the past decade. The pace of generation of C&D waste is also significant. In general, there are two sources for generation of waste materials, namely, bulk generators and retail or small generators (Thomas & Wilson, 2013)

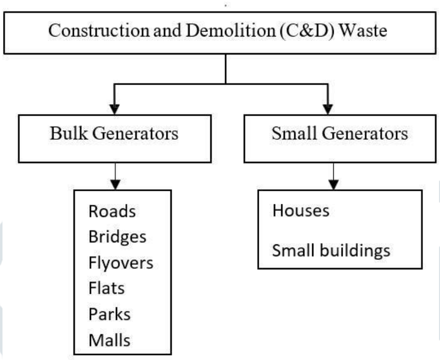

Figure 1. Sources of waste generation

This category of waste is complex due to the different types of building materials being used, but in general may comprise the following materials (Hemalatha, Prasad, & Subramanya, 2008):

Table 1. Major and Minor components of waste generated

Major Components	Minor Components
□ Cement Concrete □ Bricks □ Cement plaster □ Steel (from R.C.C, door / window frames, roofing supports, railings of staircase etc) □ Rubble □ Stone (marble, granite, sand stone) □ Wood /Timber (especially demolition of old buildings)	□ Pipes (GI, Iron, plastics) □ Electrical fixtures (Copper/ aluminium wiring, wooden baton, bakelites/ plastic switches, wire insulation) □ Panels (wooden, laminated) □ Others (glazed tiles, glass panes, and paints)

Research on the categorization of C&D waste yielded the following conclusions (Ghosh, Haldar et al. 2016).

- Non-Recyclable materials– RCC, Bricks (Damaged), Plastering materials and lime concreting (Major), Mixed Earth (Minor).
- Recyclable materials-Steel and Bricks (Major), wood, sanitary pipes, Glass (Minor).

Only the major components were included in the optimization model to avoid lengthening and unnecessary complications. Various researchers have emphasized the importance of concrete and brick waste as a resource for new construction. The researches have been conducted and they recommend waste reuse as recycled concrete, re- cycled aggregate concrete, brick from waste has potential as a pozzolanic material in the partial replacement of cement, use of waste-brick material in brick production etc.

It was found from the literature study that crushed concrete was used to replace up to 20% of coarse aggregates (Batayneh, Marie, & Asi, 2007). Another experiment with recycled concrete aggregate (0–65%) as coarse aggregate replacement indicates that high volumes of waste materials could be used in concrete without a significant reduction in the mechanical and durability (namely water absorption and electrical resistivity) properties of the concrete (Biglarijoo et al., 2017). In some experiment three varieties of concrete mixtures were prepared, whereby they each contained different amounts of concrete waste of 0%, 5% and 15%, respectively to test them (Rosman, Abas, & Mydin, 2014). A researcher developed C&D waste brick of size 225 mm × 115 mm × 75 mm for the two different compositions namely; Cement and fly ash were used as a binder along with C&D waste as replacement for natural coarse and fine aggregates. The tests were carried out as per Indian Standards for the desired composition (Agarwal & Krishan, 2017). The paste made from waste brick obtained from building C & D wastes has the pozzolic characteristics and can be used as a pozzolanic material in the partial replacement of cement.

The waste-brick material is also investigated in brick production. The effects of recycling of waste brick material on the durability and mechanical properties of the bricks were analysed. Different tests conducted included workability, unit weight, compressive strength, flexural strength, and indirect tensile strength (splitting) tests. In most of the cases the material obtained from demolished has proved to bear properties comparable with the conventional materials. These wastes can be reused successfully as partial substitutes for sand or coarse aggregates in concrete mixtures.

V. EXPERIMENTS CONDUCTED

The study includes collection of waste from construction sites and experimental test to verify its suitability for replacement in pavers.

Sources of Material

The concrete waste and brick waste was collected from construction sites and prepared to be worked upon for the study. Labour was hired for two purposed; (1) breaking the concrete waste into aggregates of size 10-20 mm approximately and (2) to convert waste brick into powder for reuse. Further sieve analysis test was conducted before reusing the waste products.

The study is focused on making Concrete Paver Blocks by partial replacement of Waste Concrete and Waste Brick.

Test performed on materials:

- Sieve Analysis of Coarse Aggregate
- Sieve Analysis of Fine Aggregate
- Specific Gravity of Cement
- Specific Gravity of Coarse Aggregate
- Specific Gravity of Fine Aggregate

On the basis of test performed in the lab the Concrete Mix Designed for M30 has been done.
The Proportion is 1 : 1.43 : 2.54 (cement, fine aggregate and coarse Aggregate respectively) and 0.44 water.

Cube casting and testing on CTM (Compression Testing Machine):- IS 10262 : 2009

Table 2. Various % used for replacement

Waste	**Replacement**		
Crushed Concrete as coarse aggregate	10 %	20 %	30 %
Brick Powder as fine aggregate	5 %	10 %	15 %

Total number of cubes has been casted is 42. And the cubes were tested for 7th day strength and 28th day strength.
Nominal cube = 3 cubes at 7th day and 3 cubes at 28th day casted on 20/02/2019
Material for one cube:- Cement = 1.57 kg
Coarse sand = 2.25 kg
Stone = 3.99 kg
Water =0.690 kg
Cube with 10% replacement of waste concrete as coarse aggregate = 3 cubes for 7th day strength, casted on 20/02/2019
Material for one cube:- Cement = 1.57 kg
Coarse sand = 2.25 kg
Stone = 3.99 kg
Waste concrete = 0.399 kg
Water =0.690 kg
Cube with 20% replacement of waste concrete as coarse aggregate = 3 cubes for 7th day strength, casted on 20/02/2019
Material for one cube:- Cement = 1.57 kg
Coarse sand = 2.25 kg
Stone = 3.99 kg
Waste concrete = 0.798 kg
Water =0.690 kg
Cube with 30% replacement of waste concrete as coarse aggregate = 3 cubes for 7th day strength, casted on 25/02/2019

Material for one cube:- Cement = 1.57 kg
Coarse sand = 2.25 kg
Stone = 3.99 kg
Waste concrete = 1.197 kg
Water = 0.690 kg

Table 3. Results of Test on 7th day (values in N/mm^2)

CUBE	SAMPLE 1	SAMPLE 2	SAMPLE 3	AVERAGE
Nominal cube	23.6	24.4	25	24.3
10% replacement	23.1	22	23.3	22.8
20% replacement	18	19	18	18.3
30% replacement	16.6	18	16	16.8

Table 4. Results of Test on 28th day (values in N/mm^2)

CUBE	SAMPLE 1	SAMPLE 2	SAMPLE 3	AVERAGE
Nominal cube	36.5	36	37	36.5
10% replacement	33	33.2	33.7	33.3
20% replacement	28	29	28.6	28.5
30% replacement	25.5	26.6	25	25.7

Since the maximum value got on 10% replacement of waste concrete as coarse aggregate. So, the replacement of brick powder as fine aggregate (5%, 10% & 15%) has done with 10% replacement of waste concrete.
So, the combinations are:

05% brick powder and 10% waste concrete
10% brick powder and 10% waste concrete
15% brick powder and 10% waste concrete

Then the number of cube casted :- 18

Cube with 05% brick powder and 10% waste concrete = 6 cubes for 7th and 28th day strength, casted on 05/03/2019
Material for one cube:- Cement = 1.57 kg
Coarse sand = 2.25 kg
Waste Brick powder = 0.1125 kg
Stone = 3.99 kg
Waste concrete = 0.399 kg
Water = 0.690 kg

Cube with 10% brick powder and 10% waste concrete = 6 cubes for 7th and 28th day strength, casted on 05/03/2019
Material for one cube:- Cement = 1.57 kg
Coarse sand = 2.25 kg
Waste Brick powder = 0.225 kg
Stone = 3.99 kg
Waste concrete = 0.399 kg
Water = 0.690 kg

Cube with 15% brick powder and 10% waste concrete = 6 cubes for 7th and 28th day strength, casted on 05/03/2019
Material for one cube:- Cement = 1.57 kg
Coarse sand = 2.25 kg
Waste Brick powder = 0.3375 kg
Stone = 3.99 kg
Waste concrete = 0.399 kg
Water = 0.690 kg

Table 5. Results of Test on 7th day (values in N/mm^2)

CUBE	SAMPLE 1	SAMPLE 2	SAMPLE 3	AVERAGE
05% and 10%	17	16.5	18	17.2
10% and 10%	16	16.5	16.5	16.3
15% And 10%	15	14	15.5	14.8

Table 6. Results of Test on 28th day (values in N/mm^2)

CUBE	SAMPLE 1	SAMPLE 2	SAMPLE 3	AVERAGE
05% and 10%	27	26	28	27
10% and 10%	26	25.8	26	25.9
15% And 10%	24.5	24.2	24	24.2

The conclusion of the test carried on the cubes is that the maximum value is obtained at the replacement of 5% waste brick powder as fine aggregate and 10% waste concrete as coarse aggregate. The reduction in the strength is acceptable because of replacement of both fine as well as coarse aggregate materials. Hence, the strength of replaced material concrete is 27 N/mm^2.

VI. RESULTS AND DISCUSSION

Cost Analysis has been done for reuse of waste as Pavers for making 100 meter road, in the following way;
Length = 100 m
Width = 4 m
Height = 0.05 m
Volume = 20 cum
Since, material used in making cube of 15 cm = 8.5 kg (as cube weighted in lab)

0.15 x 0.15 x 0.15 cum = 8.5 kg material
0.003375 cum = 8.5 kg
And in 1 cum = 2518.518519 kg material

So, in 20 cum = 20 x 2518.518519
= 50370.37037 kg material

Where the quantity of material for normal pavers without replacement,
Cement: 1/((1+1.43+2.54+.44)) x 50370.37037 = 9310.604505 kg (187 bags)

Fine Agg. : 1.43/((1+1.43+2.54+.44)) x 50370.37037 = 13314.16444 kg
(the bulk density of coarse sand is in the range of 1520 – 1680 kg/m3, therefore minimum quantity is 309.337 cu ft)

Coarse Agg. : 2.54/((1+1.43+2.54+.44)) x 50370.37037 = 23648.93544 kg
(the bulk density of stone gavel is in the range of 1560 – 1600 kg/m3, therefore minimum quantity is 535.359 cu ft)

Water: 0.44/((1+1.43+2.54+.44)) x 50370.37037 = 4096.66 ltr

Cost of normal paver block for road :-
Cement at the rate of Rs. 350 per bag = 187 x 350 = Rs. 65450
Fine agg. at the rate of Rs. 50 per cu ft = 309.337 x 50 = Rs. 15466.85
Coarse agg. at the rate of Rs. 50 per cu ft = 530.359 = Rs. 26767.95

TOTAL = Rs. 107685

Now, the quantity of material for pavers with replacement is as follows:
Cement: 1/((1+1.43+2.54+.44)) x 50370.37037 = 9310.604505 kg (187 bags)

Fine Agg.: 95 % weight of fine agg. in normal paver :
= (13314.16444 x 95)/100 = 12648.4562 kg (293.87 cu ft)

Brick Waste: 5% weight of fine agg. in normal paver = (13314.16444 x 5)/100 = 665.7082 kg
(the bulk density of brick is 1900 kg/m3, therefore quantity is 12.373 cu ft)

Coarse Agg.: 90 % weight of coarse agg. in normal paver :
= (23648.93544 x 90)/100 = 21284.04196 kg (481.82 cu. Ft.)

Waste Concrete: 10 % weight of coarse agg. in normal paver = (23648.93544 x 90)/100
= 2364.893544 kg
(the bulk density of concrete is 2400 kg/m3, therefore quantity is 34.8 cu. ft.)

Water: 0.44/((1+1.43+2.54+.44)) x 50370.37037 = 4096.66 ltr

Cost of normal paver block for road :-

Cement at the rate of Rs. 350 per bag	= 187 x 350	= Rs. 65450
Fine agg. at the rate of Rs. 50 per cu ft	= 293.87 x 50	= Rs. 14693.5
Coarse agg. at the rate of Rs. 50 per cu ft	= 481.82 x 50	= Rs. 24091

Taking waste material free of cost but transportation cost applied.

Transportation cost for 100 cu ft material		= Rs. 300
So, the cost of 12.373 cu ft Brick waste	= 12.373 x 300/100	= Rs. 38
And the cost of 34.8 cu ft concrete waste	= 34.8 x 300/100	= Rs. 105
2 labours cost at the rate of Rs. 400 per labour for crushing concrete and grinding brick		= Rs. 800

TOTAL = Rs. 105178

Thus we conclude from the cost analysis that the replacement (of cement and aggregate) in the paver block reduce the cost of paver by Rs.2507 per 100 meter run.

VII. CONCLUSION

The study concludes that brick and concrete waste generated from construction sites has a lot of scope for reuse as block pavers and these can be reused as resources for future construction materials to save environment.

The experimental test was performed on pavers by changing the composition of brick and concrete waste and we obtained the composition at which the maximum value of strength was observed. From the test performed we conclude that the concrete pavers can be made by replacement of 5% brick waste as fine aggregate and 10% concrete waste as coarse aggregate. From the cost analysis it is clear, that the cost of paver is reduced by Rs. 2507 per 100 meter run.

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