

## Use of C&D Waste in Development of Sustainable Walling Block

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### Abstract

Due to the increasing land pressures the need to demolish old structures to make way for new ones is always going to increase. This leads to proliferation of construction waste and the problems attached to solid and construction waste management. This project aims to make a sustainable use of this construction and demolition waste. Survey of the study region was carried out to understand and quantify the construction and demolition waste scenario. The construction and demolition waste was procured, segregated, processed and developed into a sustainable walling block (SWB). This block was tested for its physical-mechanical and thermal properties. The results were compared with commercially available units. The energy savings were determined by assessment tool of TERI and it was found that a considerable amount of energy can be saved.

The results show that the developed SWB are a feasible and proper method of utilization of waste generated by construction industry

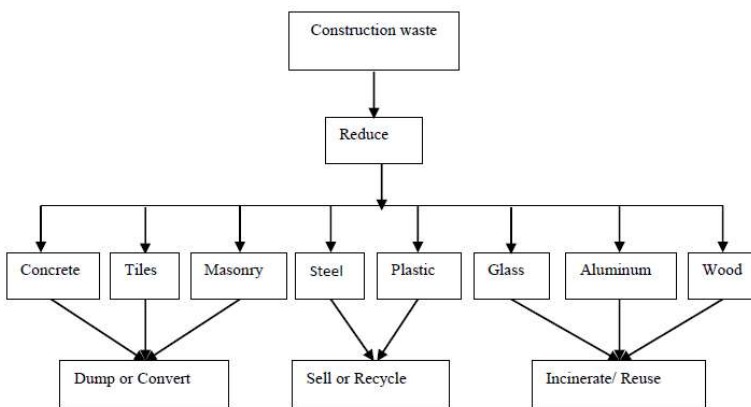
### Keywords

C&D waste, Thermal Conductivity, Sustainable Walling Block

### Introduction

Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs. A major hurdle in the path towards sustainable development is the improper handling of waste generated by various industries. Solid waste is an exponentially rising problem that will affect the future generations. Construction and demolition (hereafter referred as C&D) waste albeit just a chunk of a very large problem, is exponentially rising.

Globally the estimated quantity of construction wastes generation was 12 billion tons in the year 2002. Annually, Asia alone generates 4.4 billion tons of solid wastes. Most of the Asian countries including PR China, India, Sri Lanka, Thailand and Vietnam do not have specific regulations designed for disposal of C&D wastes [1] In India about 14.5 MT of solid waste is generated annually from construction industry that includes waste sand, gravel, bitumen, bricks, masonry, and concrete. The entire mechanism of C&D waste is depicted in the Fig 1.



**Fig 1: Generation and Disposal of Construction Waste at New Construction Sites[2]**

What is it that inhibits from recycling construction aggregates, when concrete is 81-85% aggregate. The problem according to a study commissioned by Technology Information, Forecasting and Assessment Council (TIFAC), 70% of the construction industry is not aware of recycling techniques. [3] On the other hand unavailability of economical solutions for processing of C&D waste inhibits the producer in construction industry to recycle it. These wastes are thus generally used in filling/levelling of low-lying areas or dumped elsewhere. Furthermore there are no tangible incentives to the construction organizations which try to recycle and reuse these wastes. To increase the quantum of recycling and reusing C&D waste, there is a need for concentrated efforts to legislate rules to counter the problem of such waste. Recycling of wastes into sustainable, energy efficient construction materials is a viable solution for the problem of pollution and

natural resource conservation for future generation. The detailed literature review was carried out to explore the potential of construction waste as a raw material in the manufacturing of new building materials. The concept of developing new building material out of the waste was evolved. In past several studies have been carried out to validate the suitability of C&D waste as a construction material. It was found that sand produced from C&D waste is similar in grading of the original sand fraction present in the total waste [4]. Recycled coarse aggregate can be used as a potential replacement for natural coarse aggregate in concrete production [5]. Also studies have been carried out to develop bricks with waste bricks aggregates [6, 7]

The building has two components of energy, i.e. embodied energy (EE) and operating energy (OE). EE is sequestered in building materials during all processes of production, on-site construction, and final demolition and disposal. OE is expended in maintaining indoor environment comfortable through mechanical means such as heating and cooling, lighting and ventilation appliances [8]. In any energy efficient building envelop of building plays a very major role. Building envelop comprises of Roof and walls. Where, concrete and bricks/blocks are used respectively to construct roof and walls. Thermal properties of these building blocks affects the heat gain inside the building envelop and in turn the consumption of operational energy. Heat transfer is directly proportional to the thermal conductivity (k) of a material and thermal transmittance (U) value of an assembly. Thermal conductivity depends on porosity of a material. Aggregates recovered from C&D waste contains brick bats, tiles, and aggregates containing adhered mortar on it. These materials are more porous than naturally occurring aggregates. Thus help in reducing thermal conductivity of the blocks/bricks manufactured using C&D waste [9]. Thermal insulation capacity of walling material can further be improved by using insulated bricks [10].

Conserving the natural resources (energy, material and water & land) and reducing EE and OE of building, while achieving comfortable atmosphere inside the building, is the need of present scenario. The scenario demands for a solution which addresses the issues of solid waste, embodied energy, embodied carbon and thermal comfort in the building at optimum cost. The material developed by the researcher satisfies all purposes simultaneously. In the present study the C&D waste in study region was quantified by a questionnaire based survey. The data was collected, filtered and analyzed. C&D waste from site was segregated and procured. Segregated concrete and masonry waste was crushed, sieved and tested according to the Indian Standards. Samples for SWB were prepared. Physical, mechanical and thermal testing of SWB was carried out. Comparative study of SWB and commercially available materials was carried out. To validate the saving in energy due to the use of SWB, energy saving assessment tool “EnEff ResBuild India” published by TERI was used [11].

## **Materials and Methods:**

### **Collection of Raw material**

To assess generation of construction waste at new construction sites over the study area, a survey was carried out over ongoing large townships in Nagpur, India. Similarly, registered demolishers were interviewed to assess the quantity of C&D waste. In all, fifteen townships out of a total ongoing sixty projects were surveyed. While collecting the data for C&D waste, list of registered demolishers in the area was collected from municipal authority. Collected data showed that wood, plastic, packaging material and metallic items were in a range of 1-20% of original quantity used which were sold as scrap by owners for recycling. Concrete chunks, masonry waste and tiles waste were in a range from 1-5% of the original quantity used. This material was being dumped as landfill at most of the projects. The C&D waste was collected from the residential site located near National Research Centre for Citrus, Nagpur. The waste procured from the site was then brought to laboratory and segregated as brick waste, concrete and tiles.

### **Casting of SWBs**

The raw materials used to cast SWBs were C&D waste in two parts; recycled concrete aggregates (RCA) and Recycled Brick aggregate (RBA), Ordinary portland cement of grade 43 complying to IS 8112:2013, Fly Ash, Sand. The C&D waste that was procured and segregated was then crushed manually and sieved to be used further. The aggregates passing 12.5mm and retaining 4.75mm were selected as coarse aggregates. In the subsequent samples, brick dust was also used along with sand, albeit in small proportions

To cast SWBs, at first a control sample, Sample A, was casted having 100% recycled concrete aggregates (RCA) Fig 2. In the subsequent samples the percentage of RCA was reduced and RBA were included. This was done due to the humungous weight of Sample A. Sample B had 50-50% proportion of RCA and RBA s by weight. In Sample C, the percentage of RBA s was increased further it had 70% RBA s and 30% RCA. Sample D had 70% RBA s and 30% RCA but along with sand, brick dust was also used as a fine aggregate. Sample E was casted with an insulator embedded in it. Expanded Polystyrene was used as filler insulation. Expanded polystyrene (EPS) is rigid and tough, closed-cell foam. It is usually white and made of pre-expanded polystyrene beads. This is available commercially in form of molded sheets for building insulation and as

packing material for cushioning fragile items. The designation of samples and proportion of materials is given in Table 1.

Mix Notation	Proportion	Binder		Fine Aggregate		Coarse Aggregate		Insulator
		Cement	Fly Ash	Sand	RBA Dust	RCA	RBA	
Sample A	0:100	3	0	6	0	12	0	No
Sample B	50:50	3	0	6	0	6	6	No
Sample C	60:40	2.1	0.9	6	0	4.8	7.2	No
Sample D	70:30	2.1	0.9	6	0	3.6	8.4	No
Sample E	70:30	2.1	0.9	3	3	3.6	8.4	Yes

**Table1: Proportion of Materials in Samples**

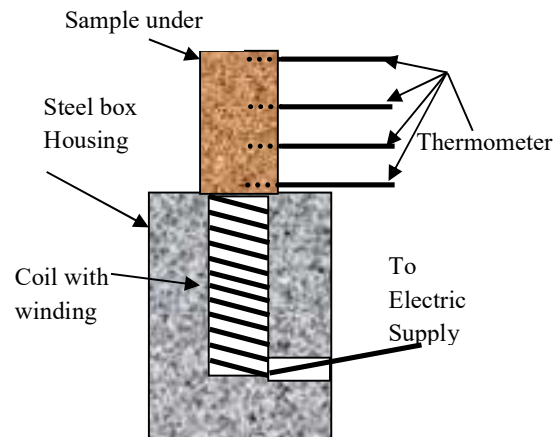
A wooden mould for the casting was fabricated to cast six SWBs of 220 mm x 90 mm x 75mm size each [Fig. 2]. The SWBs were casted in wooden formwork, de-molded and cured. Density, water absorption, compressive strength for the SWBs were calculated as per prevalent IS standards [12, 13, 14].

### Calculation of Thermal Properties

Thermal conductivity of the developed SWBs was determined. Test was conducted for in-air thermal conductivity with the help of an apparatus [15] which has two parts; furnace and temperature measurements. Furnace comprised of, a hollow alumina core was wound with the tempered Ni-chrome Coil and was housed in a steel box. The winding was insulated with asbestos rope and ceramic cotton. The space around core winding was insulated by the means of fire bricks, fire clay and fire cement. A hole in the cover of box was cut to mount the specimen. The coil was connected to electric supply so as to provide heat to the specimen. A dimmer-stat was connected to regulate the voltage, which controlled the temperature of the furnace. Sample was prepared by drilling holes in brick specimen at sufficient intervals to house thermometers. Sample was then mounted on the hole of furnace cover. The electric supply was started and heat was provided to the sample. Observations at desired time interval were recorded and calculations were done. The schematic is given in Fig 3.



**Fig 2: Casting of Specimen**



**Fig 3: Thermal Conductivity Test Apparatus**

Thermal transmittance of wall assembly was calculated for the developed SWB. The U-factor or U-value is the overall heat transfer coefficient that describes rate of transfer of heat (in watts) through one square meter of a structure divided by the difference in temperature across the structure. A smaller U-factor is better at reducing heat transfer. It is expressed in  $W/m^2K$ . Wall assembly comprised of one layer of developed SWB (Sample E) in header, 25 mm external and 12.5 mm internal plaster.

### Calculation of Saving in Energy

To validate the reduction in energy requirement because of developed SWB a comparative study was carried out with a simulation tool. For this purpose "EnEff ResBuild India" an open source tool developed by "The energy resources institute" (TERI) and Fraunhofer Institute, Germany [16].

## Results and Discussion

Physical properties of C&D aggregates are given in Table 2.

	C&D aggregate		
	Natural aggregate	Recycled Concrete aggregate	Recycled Brick aggregate
Water absorption	0.5%	3.15 %	19.75%
Flakiness index	11-35%	39.43 %	-
Elongation index	10-37%	17.61%	-
Impact value	17-41%	29.85%	-

**Table 2: Physical Properties of C&D Aggregates**

As evident from Table 3, water absorption of the RCA is much higher than that of the natural aggregate. This excessive water absorption is attributed to the mortar that remains adhered. The increased water absorption in the test samples is due to the increase in percentage of RBA in the samples. The flakiness index of the RCA is higher than that of the normal aggregate. This is because the aggregates were manually crushed and hence the shape and size of the aggregate cannot be controlled.

Physical and mechanical properties of SWB are given in Table 3.

Sample	Density (kg/m <sup>3</sup> )	Water Absorption (%)	Compressive Strength (MPa)
Sample A	2392.49	5.18	28.31
Sample B	2402.59	6.00	19.05
Sample C	2170.99	6.41	17.39
Sample D	2008.65	6.83	14.88
Sample E	1490.62	7.93	7.64

**Table 3: Physical and Mechanical Properties of SWB**

Sample A, Sample B, Sample C, Sample D have higher density because of high percentages of RCA. Sample E has the least density because of higher proportion of crushed RBA s; the reduced density is also due to the presence of insulator embedded in it. The density of insulator material is 12 kg/m<sup>3</sup> and this occupies 10% of the volume of the SWB. The density of Sample E is found to be 1490.62 kg/m<sup>3</sup>. Similarly water absorption of samples increases and compressive strength of samples decreases from A to E due to increased proportion of RBA s.

Thermal conductivity test was performed on two samples, Sample D and Sample E. Thermal conductivity of Sample D is 0.17Wm/k and that for Sample E (insulator) is 0.12Wm/k.

### Comparison to Commercially Available Materials

The SWBs casted were compared with the commercial bricks available in the market. The bricks were compared under the heads compressive strength, density, water absorption and thermal conductivity. Table 4 gives the comparison of different properties of bricks. Representative samples were procured from market and tests were carried out in laboratory.

Material	Density (kg/m <sup>3</sup> )	Water Absorption %	Compressive Strength (MPa)	Thermal conductivity W m/k
AAC	726.0	27	3.0	0.16
CLC	1190.5	38	3.28	0.15
Fly-ash bricks	2200.6	15.94	3.56	1.05
Red clay bricks	1866.8	19.32	5.1	0.81
Sample A	2392.49	5.81	28.31	-
Sample B	2402.59	6.006	19.05	-
Sample C	2170.99	6.41	17.35	-
Sample D	2008.65	6.83	14.88	0.17
Sample E	1490.62	7.93	7.64	0.12

**Table 4: Comparison of Properties of Developed SWB with the Commercial Bricks**

The sample SWBs when used in the assessment tool instead of conventional bricks, the percentage energy saving is 20%. There is an energy saving because the load or tonnage on air conditioners or heating instruments used decreases. This decrease is observed as the temperature inside a building is considerably controlled as compared to the outside temperature. The energy saving done by Sample E is shown in the assessment tool's window in Fig 6 and that of Sample D is shown in Fig 7.

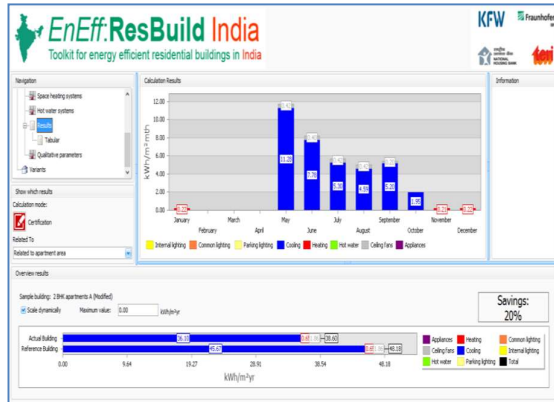


Fig 4: Report to Tool for Energy Saving Due to Sample E

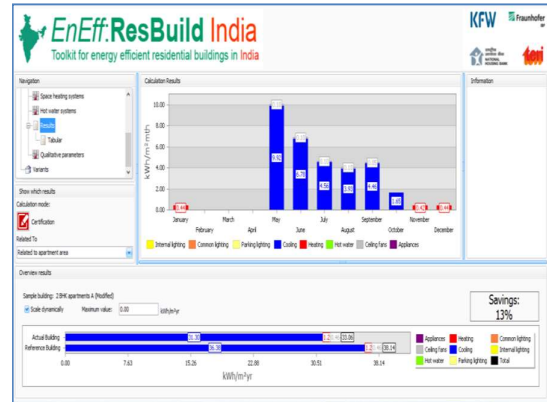


Fig 5: Report to Tool for Energy Saving Due to Sample D

### Conclusion

The study concludes that masonry waste portion out of C&D waste can be utilized as a raw material for the development of new construction material & thus a solution to the solid waste management problem. Manufacturing of SWB from C&D waste eliminates environmental impact of land filling and solid waste dumping.

The compressive strength is more than the values suggested in IS code and also higher than the materials available in market. Compressive strength of Sample E of SWB was found to be 60.73, 57.07, 53.40 and 33.25% more than AAC, CLC, Fly ash and Red clay bricks respectively.

Water absorption of the Sample E of SWB is within the limits as prescribed by IS code and is much lower than that of the walling materials available in market. Water absorption of Sample E for developed material found to be 240%, 379%, 101% and 144% less than AAC, CLC, Fly ash and Red clay bricks respectively.

Density of Sample E for developed material is 105% and 25% more & 32% and 20% less than AAC, CLC and Fly ash and Red clay bricks respectively.

From the observations and conclusions drawn it is recommended that Sample E with insulator can successfully be used as a sustainable walling material the construction projects. This is due to its high thermal performance, low water absorption, and good compressive strength. Insulating property of sample E helps in reducing overall energy consumption in a typical building by 20%.

### Acknowledgement

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