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Reusability of Construction & Demolition waste in bricks

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Abstract - *Construction and Demolition (C&D) waste, a major component of the solid waste is defined as a waste resulting from the construction, renovation and demolition of structures. Till date a significant portion of C&D waste is disposed of in the landfills which not only consumes a considerable amount of landfill volume but also leads to environmental and health risks. As construction cost increases and land area gets scarcer, it becomes vital to take measures that incorporate a solution to the same. Developing a sustainable construction material (brick) using construction and demolition (C&D) waste by diversion of C&D waste from the main waste stream can help in gaining a substantial area of land. The present study aims to develop C&D waste brick of size 225 mm × 115 mm × 75 mm for the two different compositions (F-type & C- type). Cement and fly ash were used as a binder along with C&D waste as replacement for natural coarse and fine aggregates. Physical and mechanical testing (compressive strength and water absorption) was carried out as per Indian Standards for the desired composition. The results were compared to the standard values of commercially available clay bricks. Amongst both, C-type brick having composition in the ratio 1:2.75:2.25 (binder: fine aggregate: coarse aggregate) exhibit compressive strength (9.91 N/m²), water absorption (8.8%) and self-weight (3.6 kg) within the limits of Indian Standards. The developed sustainable product can practically be implemented over any location specified by the manufacturer and serve the purpose of solid waste management.*

***Key Words*: Construction& Demolition waste, C&D waste management, Recycling, C&D bricks, Compressive Strength test, solid waste management**

1. INTRODUCTION

Increase in population and rapid urbanization are the main culprits of solid waste generation. It is well known that the rise in population is at its full pace and today India holds second in the world in terms of population. Along with this more and more people are adopting the urban lifestyle. In 2011, Census of India recorded increase in a total number of towns from 5,161 in 2001 to 7,935 in 2011. Moreover, it is predicted that by 2050 as many people will live in cities as the population of the whole world in 2000 [1]. With more people moving towards urbanization, the amount of waste generated is increasing in towns/cities.

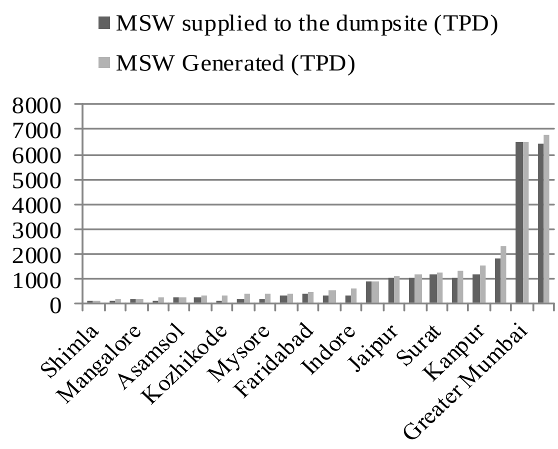

Chart 1: Quantum of Municipal Solid Waste (MSW) in TPD as per FICCI study, 2011

Such humungous increase of solid waste demands an efficient eco-friendly disposal solution in 2014, Center for Science and Environment estimated, globally, cities generate about 1.3 billion tons of solid waste per year. This volume is expected to increase to 6 billion tons by 2025, says a 2012 report by the World Bank. As per the article in Times of India, a study by Building Materials and Technology Promotion Council (BMTPC) and Centre For Fly Ash Research and Management (C-FARM) in 2016 showed that the annual generation of solid waste in India itself was 165 - 175 MT with a treatment capacity for such waste merely being 2000 tonnes per day. It occupies considerable storage space either on roadsides or landfill. Planning Commission Report, 2014 reveals that by 2031 about 23.5 × 10^7 cubic meters of landfill space will be required which in terms of the area would be 1,175 hectares of land per year with waste pilled in 20 m of height will be required to dispose of the waste. The mainstream of solid waste has a broad range of incoming sources; residential, industrial, construction & demolition, commercial, manufacturing, institutional, and agricultural [2]. Construction & Demolition (C&D) Waste accounts for 25% of this total quantum of solid waste generated in India. In the past decade, a great deed of investment has been made in the construction industry. Technology, Information, Forecasting and Assessment Council –TIFAC (2000) estimated the total construction works in the country for the five years during 2006-2011 to be worth $847 [3]. With fast sprawling construction industry, the generation of C&D waste is also at full pace.

Spivey in 1974 made one of the earliest efforts to classify C&D waste based on the common components of onsite wastes as follows [4]:
(1) Demolition materials like concrete, brick, wallboard, plaster, and used lumber
(2) Packaging materials like paper, cardboard, plastic and metal retaining bands
(3) Wood including trees and scrap lumber
(4) Asphalt and waste concrete
(5) Sanitary waste and garbage
(6) Scrap-metal products
(7) Rubber, plastic, and glass; and
(8) Pesticides and pesticide containers.
Amongst all, materials like glass, aluminium, plastic and metal are recyclable and have scrap value but concrete and brick masonry remain to be disposed of in a landfill [5].

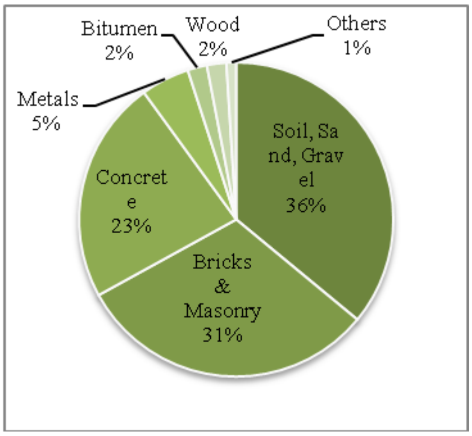

Chart: 2 Composition of C&D waste as per NBM & CW, December 2015

Concrete and bricks form the majority of C&D waste and dumping it in landfills further complicates the problem. Central Intelligence Agency reports, 57% of the total land area (3,287,263 km^2) falls under agriculture and of the remaining 23.6% is occupied by forest. This leaves us with only 16.4% (539,111 km^2) of the area for permanent meadows and pastures, forests and woodlands, built-on areas, roads, barren land, etc. of which 11.75 km^2 of land will be required annually for landfilling of C&D waste by 2030. Bringing more land under use for waste management purpose will only mean compromising with the human needs. So there has to be a way that makes efficient use of the concept of 3R's i.e. Reduce, Reuse, Recycle.

There are two major ways to approach C&D waste management: First, to assess and control the factors leading to the generation of waste and second to reuse the generated waste. Several studies suggest that utilization of solid waste is not only a viable option to Waste Management [6] [7] but also desirable—socially, economically, and environmentally [8] [9] [10] [11].

Central Road Research Institute (CRRI) carried out the "Feasibility study on the use of C&D waste in roadwork". The study found potential feasibility for application in (a) embankment and sub-grade construction, (b) sub-base construction, (c) stabilized base course construction and (d) rigid pavement construction. But again this is not adopted on a magnificent scale. Also, another plausible use of C&D waste is in the manufacturing of recycled aggregates to replace with the natural ones in concrete [12]. All these though have a great potential but not enough to tackle almost 50% of C&D waste that is generated in the form of bricks and concrete (Figure 2).

In a study to make sustainable bricks using sludge, construction and demolition waste as an essential ingredient, the sludge was found to have properties comparable to that of clay conventionally used for manufacturing of bricks. Also, with every 10% increase in sludge the compressive strength reduced by 0.3 N/mm^2 approx and a rise in water absorption was seen [13]. The present study aims to work out a possible use of C&D waste (concrete and masonry) in the manufacturing of bricks that have an acceptable value of compressive strength and water absorption.

2. Methods and Materials

2.1 Materials & Machinery Used

Ordinary Portland cement and fly ash were used as a cementitious material. C&D waste from the major components of the bricks and were used as coarse and fine aggregate.

2.2 Collection and Preparation of Materials

Both cement and fly ash are commercially available in the market and were procured from the same. For coarse and fine aggregates about 40 kilograms of C&D waste was collected from a residential housing construction site of Assotech the Nest in Ghaziabad, Uttar Pradesh, India. The segregation of concrete and masonry from the recyclable waste such as steel, pipes etc. was performed at the site itself. The waste (concrete & masonry) was crushed and sieved through a sieve of 4.75 mm and 10 mm. The ones below 4.75 mm were used as fine aggregate and of that size between 4.75 mm to 10 mm were used as coarse aggregates. The brick mold was obtained from the clay brick manufacturing kiln in Greater Noida.

2.3 Fabrication process

Bricks with two different compositions were fabricated. The brick composed of cement and fly ash is referred as F-type and the ones having only cement is C-type. Four bricks of each type were fabricated and named as F-1, F-2, F-3, F-4, C-1, C-2, C-3 and C-4 respectively. All the materials i.e. cement, fly ash and sieved C&D waste were weighed in appropriate proportions (shown in table-1) and mixed manually keeping the water to binder ratio of 0.6. The prepared mix was poured into the mould and was subjected to manually applied pressure. After 20-30 minutes of setting the time the bricks were de-moulded and left to dry on the wooden pallets for 3 days. The dried bricks were then cured for 7 days before testing.

Table 1: Compositions of raw materials for bricks (by wt.)

Mix Notation	Cement	Fly ash	C&D waste	
			Fines	Aggregates
F-type (with fly ash)	280.83g (8.33%)	280.83g (8.33%)	1544.58g (45.83%)	1263.75g (37.5%)
C-type (without fly ash)	605g (16.67%)	-	1663.7g (45.83%)	1361.25g (37.5%)

2.4 Physical and mechanical tests

Physical and mechanical tests performed were hardness, efflorescence, water absorption and compressive strength were conducted to check the suitability of developed material. All tests were performed as per the Indian Standard codes for methods of tests of burnt clay [14]. The obtained results were compared to the properties of clay bricks as mentioned in Indian Standard codes for common burnt clay building bricks – specification [15].

3. RESULTS AND DISCUSSION

The bricks, when tested for hardness by dropping from a height of 1 meter above ground appeared to develop no cracks. Going by the procedure for efflorescence test, there was no difference observed in the appearance of the brick samples of both F-type and C-type. Hence we can say as per Table 2 the brick samples were "not effloresced". This obviates any defects like unhygienic appearance, dampness of walls, crumbling of plaster to name a few. Similar results were observed for the brick made using sewage sludge [13].

The results of the water absorption and compressive strength test are tabulated in Table 3 & 4 respectively. The comparison of these properties with the specifications of common burnt clay bricks as indicated in IS 1077:1992 is plotted in Figure 4 & 5. The C&D waste bricks possess improvised compressive strength and reduced water absorption when compared to conventional burnt clay bricks. It was seen that replacement of fly ash with Ordinary Portland Cement resulted in an increase of overall brick weight by an average of approximately 250 grams. Moreover, the compressive strength almost doubled from 5.04 N/mm^2 for the C-type brick (without fly ash) which is well within the specifications of IS 1077:1992. Further, it was observed that the C-type brick has a water absorption of 8.8% which is lesser as compared to F-type brick and the normal clay brick and within the Indian Standard limit of 20%. F-type brick also showed water absorption (10.34%) under the standard limits. This value was less than that of common burnt clay brick but not C-type brick. Also, the properties of F-type brick are comparable to that of brick BR90-6. BR90-6 brick is composed of cement, fly ash, sand and C&D waste in the ratio 1:1:1.5:8.5 and was considered to be a potential replacement of the conventional fly ash brick [5]. The BR90-6 brick has a compressive strength of 6.74 N/mm^2 which is just a little above than that of F-type brick. Also, as BR90-6 has a higher water absorption of 12.18% and makes use of sand in its composition, the F-type brick will be a much more potential replacement of the conventional Fly ash brick without any need for excavation of sand.

Table 2: Result of water absorption test

Brick Specimen	Normal weight	Weight after oven drying (w_1)	Saturated weight (w_2)	Water absorption %
F - 1	3355g	3227.5g	3562.0g	10.36
F - 2	3420g	3333.0g	3677.5g	10.33
C - 1	3740g	3669.0g	3938.0g	7.33
C - 2	3485g	3337.0g	3680.0g	10.27

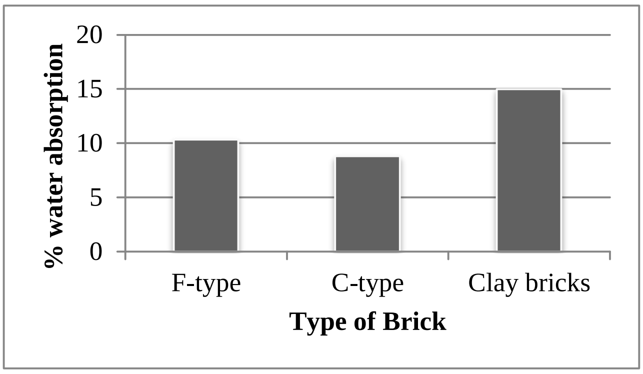

Chart 3: Comparison of water absorption of bricks

Now that both F-type and C-type bricks show results acceptable as per standard codes the selection of material will depend upon the requirement of the site. Adding, since both types of bricks show comparable water absorption that is well under maximum permissible value, the amount of load to be beard will be the deciding factor. To be on a safer side, use of C-type brick is recommended where possible for it has the better compressive strength and lower water absorption.

Table 3: Results of compression test

Brick Specimen	Load at failure	Compressive strength
F – 3	132.0 kN	5.10 N/mm^2
F – 4	128.8 kN	4.98 N/mm^2
C – 3	252.0 kN	9.74 N/mm^2
C – 4	260.8 kN	10.08 N/mm^2

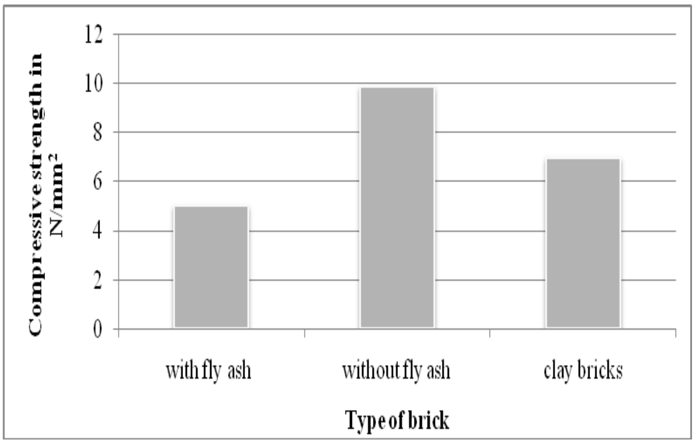

Chart 4: Comparison of Compressive Strength of bricks

4. CONCLUSIONS

The study aimed at the use of alternative material (demolished or recycled waste) for new construction which is beleaguered with normal waste in terms of debris, dust, rubbish etc. in place of conventional material. One of the major conclusions drawn from the study is that the C-type brick having a compressive strength of 9.91N/mm^2 is potentially at par with the conventionally manufactured common burnt clay bricks. This makes the C-type brick highly recommended for the application under the non-load bearing structure. Moreover, it was found that with the addition of fly ash (F-type) to the composition of bricks, a slight reduction in water absorption takes place as compared to the bricks manufactured without fly ash (C-type). Additionally, with the replacement of fly ash with Ordinary Portland Cement, normal weight of the C-type brick also increases significantly by 300 grams. Also use of these waste bricks having water absorption lesser than 10 % eliminates problems like dampness, flaking of plaster and more. Above all, use of the recommended C-type brick consumes approximately 3kg C&D waste i.e. for every 1000 bricks manufactured nearly 3 tons of C&D waste will be consumed and diverted from the mainstream. This saves us 4m^3 of fertile land which otherwise would have to be excavated for manufacturing of clay bricks and also the pollution otherwise caused from the kilns manufacturing clay bricks culminates.

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