USE OF RECYCLE PAPER MILL RESIDUE AND FLY ASH IN PRODUCTION OF WASTE-CREATE BRICKS

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ABSTRACT

Accumulation of unmanaged industrial solid waste, especially in developing countries has resulted in an increased environmental concern. Resource recovery and utilization of industrial by-product materials for making construction material has gained significant attention across the world. In this research study, recycle paper mill residue (RPMR) and fly ash (FA) are utilized to improve the properties of bricks. This research study evaluated the feasibility of utilizing RPMR and FA for making construction bricks. A homogeneous mixture of RPMR-FA-cement was prepared with fixed content of RPMR (50% by weight) and varying amount of FA (30-50% by weight) and cement (0-20% by weight). The waste-create bricks were developed from the homogeneous mixture of RPMR-FA-cement and tested in accordance with the IS codes. Characterization of RPMR and FA was performed. The SEM monographs show that RPMR has a porous and fibrous structure. The TG-DTA characterization demonstrated that RPMR can withstand temperatures up to 280 °C. The results indicate that RPMR- bricks prepared from RPMR-FA-cement combination are light weight and meet compressive strength requirements of IS 1077-1992. This novel construction material serves objectives of resource recovery through prudent solid waste management.

Keywords: *Compressive Strength; Fly Ash; Recycle Paper Mill Residue; Waste-Create Brick.*

1. INTRODUCTION

Brick is one of the important materials for construction industry. The conventional method of manufacturing bricks has left this important material aloof in advancement. The infrastructure such as buildings for housing and industry, and the facilities for handling water and sewage requires large amounts of construction materials. Since the large demand has been placed on building material industry especially in the last decade owing to the increasing population, there is a mismatch between demand-supply management of these materials. Hence to meet the continuously increasing demand, researchers are attempting to design and develop sustainable alternative solutions for the construction material. The increase in the popularity of using environmental friendly, low cost and lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting to the environment as well as maintaining the material requirements affirmed in the standards. Brick is one of the most accommodating masonry units as a building material due to its properties. Attempts have been made to incorporate waste in the production of bricks (Raut et al., 2011). Thermal conductivity can be reduced by addition of pore-forming agents (waste material) to the bricks before firing (Dondi *et al.,* 1997). Another advantage of lightweight bricks is reduced transportation costs (Hauck et al., 1998). The cementitious binder, fly ash-lime-gypsum (FaL-G), finds extensive application in the manufacturing of building components and materials such as bricks, hollow bricks and structural concretes (Singh and Garg, 1997). The by-products and residues from pulp and paper industry are managed using several approaches including land filling, incineration, use

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in cement plant and brickworks, agricultural use and composting, anaerobic treatment, recycling and others (Huet, 1982). The needs to conserve traditional building materials that are facing depletion have obliged engineers to look for alternative materials (Abang and Chandra, 1977). The developed porous and lightweight bricks with reduced thermal conductivity and acceptable compressive strength by using paper processing residues as an additive to earthenware brick to produce the pores. Chemical analysis of the paper waste and brick raw material was performed. Mixtures containing brick raw materials and the paper waste were prepared at different proportions (up to 30% by weight). The granulated powder mixtures were compressed in a hydraulic press, and the green bodies were dried before firing at 1100 0C (Mucahit and Sedat, 2009). Physico-mechanical properties such as density, strength, thermal conductivity and leachate characteristics of fired clay bricks manufactured with different percentages of cigarate butts were investigated and analysed (Aeslina *et al.,* 2010). The possible uses of the recycled slag of welding flux (SWF) was analysed in the civil construction. It was investigated the liability of SWF as substitute of sand in the production of multiple- use mortars and clay for the production of ceramic bricks (Caroline *et al.,* 2009). The manufacturing of high strength building bricks and blocks of precise dimensions and desired properties such as lacking brittleness, having energy absorbing ability, being lightweight, shock proof and having the property of thermal insulation and sound absorption from cellulosic product recycle industry waste (CPRIW) and, fibrous cellulosic product processing industry waste (FCOOIW) were investigated (Mandavgane and Ralegaonkar, 2009). Recycling of such wastes by incorporating them into building materials is a practical solution to the pollution problem.

The present paper focuses on development of waste-create bricks using RPMR-cement combination which are useful for the sustainable development of construction industry. The low cost hand operated mixing and moulding machinery has been designed and fabricated. Optimal composition of the waste-create blocks with respect to RPMR-FA-cement has been determined for various proportions by evaluating the properties. The Indian standards recommended all the performance testes have been carried out on the waste-create bricks.

2. MATERIALS AND METHODS

Recycle paper mill residue (RPMR) was obtained from M/s Madhyapradesh Paper mill, Nagpur, India and fly ash was collected from thermal power station khaperkheda, Nagpur. The paper mill mainly works in recycling the newspaper waste. The RPMR thus obtained was used for making building blocks by mixing fly ash with Portland cement in different weight proportions. Ordinary Portland cement (43- grade) confirming to Bureau of Indian Standard (BIS), IS: 12269 were used.

2.1. CHARACTERIZATION OF RPMR AND FA

Chemical analysis of RPMR and FA brick raw material was done by using Energy Dispersive X-ray Fluorescence Spectrometer (XRF, Philips, PW 1840). Proximate and ultimate analysis of RPMR was carried out using gravimetric methods. Thermo-gravimetric-differential thermal analysis (TG-DTA) (Mettler, TA 4000) was carried out to determine the thermal stability. Scanning electron micrograph photographs have been recorded using JEOL Model No. JXA – 840 A, Japan.

2.2. MIXING AND FABRICATION OF BRICKS

Hand operated hydraulic press (Figure 1) was used to make bricks of dimensions 230x105x80 mm^3. The mixes of RPMR, fly ash and cement with different compositions were prepared. RPMR weight percentage in the composition mix was fixed at 50 %. The details of the mix are given in Table 1. The different mix compositions were prepared with uniform consistency for all the samples. 60 samples each of composition (RPMR: FA: Cement) C0 (50:50:0), C5 (50:45:5), C10 (50:40: 10), C15 (50:35:15), C20 (50:30:20) were prepared.

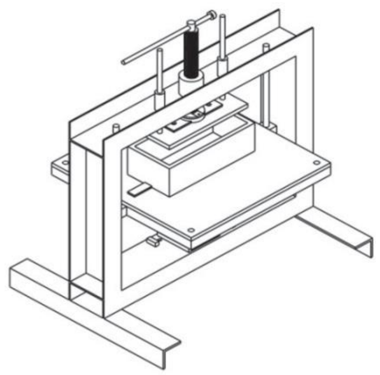

Figure 1: Design of Mould for Making Bricks Using RPMR- FA-Cement Mix

Table 1: Details of Composition

Sample Name (RPMR: FA: Cement)	Weight of RPMR (kg)	Weight of Fly Ash (kg)	Weight of Cement (kg)
C0(50:50:00)	35	35	0
C5(50:45:05)	35	31.5	3.5
C10(50:40:10)	35	28	7.0
C15(50:35:15)	35	24.5	10.5
C20(50:30:20)	35	21	14

In the mixing process of samples, RPMR fly ash and cement contents were placed in a specially designed and fabricated mixer (Figure 2) and mixed for 2 min. RPMR being fibrous in nature and lumpy, the blades of the mixer are designed to shear the RPMR mass every time it rotates. It was observed that RPMR is uniformly scattered within the mixes forming a homogeneous mixture with cement. In order to obtain more homogeneous mixes, the water was sprayed by air pump onto the mixes while the mixer is turning. Another 5 min. of mixing was conducted. Afterward, the fresh mixes are fed into the steel moulds (Figure 1). The top of the mould had uniform perforation size 3mm to let ooze moisture. The mix was pressed in the mould till 25±4% of its initial moisture was removed. The brick was taken out and kept for solar drying till its moisture further reduces by another 15±3%. The semi-dried brick was further pressed till its moisture content is reduced by 10±2% and then kept for final sun drying. As RPMR is fibrous in nature, holds moisture inside and do not let loose it easily. It was observed that if bricks were made in single stage, on drying the brick surface becomes irregular and uneven. This is because, when the bricks are made under high pressure in single stage, the pressure distribution inside the core of brick and on the surface is same and very high. As the wet bricks are solar dried, moisture from the surface evaporates developing a concentration difference of moisture between core and surface. On account of the driving force moisture at original high pressure, travels from the core to the surface. There exists pressure gradient too between the core and the surface. When the pressured moisture reaches the surface it deforms the surface and makes it irregular. Hence to keep the surface smooth on drying, the bricks are made in two stage operations.

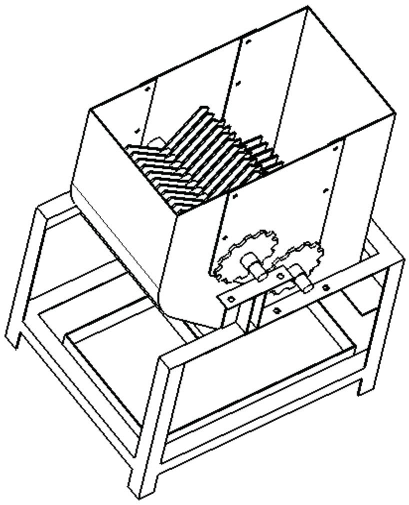

Figure 2: Design of Mixture for Mixing RPMR, FA and Cement

3. TEST METHODS

The series of tests were carried out according to IS 3495 (Part 1 to 4): 1992 to determine compressive strength, water absorption, specific weight, voidage and Efflorescence. The compressive strength was determined in a Universal Testing Machine (UTM) as per IS 3495 (Part 1):1992. For various percentages of sludge, three samples were made and subjected to a compressive strength test after complete drying, and the average strengths were obtained.

4. RESULTS AND DISCUSSION

4.1. CHARACTERIZATION OF RPMR AND FA

RPMR and FA mainly contains Si (60%) (Table 2a and 2b) depicting the XRF scan data. Table 3 gives the proximate analysis and Table 4 presents ultimate analysis.

Table 2a: Elemental Analysis of RPMR

O %	Ca %	Si %	Al %	Mg %	S %	Ti %	K %	Fe %	Na %	Cu %	P %	Cl %
15.83	14.94	60.57	2.06	3.59	1.07	0.15	0.16	0.92	0.22	0.05	0.03	0.41

Table 2b: Elemental Analysis of FA

Na_2O %	CaO %	SiO_2 %	Al_2O_3 %	MgO %	SO_3 %	TiO_2 %	K_2O %	Fe_2O_3 %	MnO %	CuO %	PbO %	Cl %
0.20	0.66	59.57	31.27	0.43	0.15	1.81	0.89	3.92	0.03	0.009	0.008	0.007

Table 3: Proximate Analysis of RPMR

Sr. No.	Wt. in grams	Moist %	Ash %	Volatile Materials %	Free Carbon %	GCV Kcal/kg
1.	420	5.8	40.6	44.7	8.9	2372

Table 4: Ultimate Analysis of RPMR

Sr. No.	Wt. in grams	C %	H %	N %	S %	O %
1.	420	22.7	2.5	0.3	0.4	23.6

According to the TG curves (Figure 3) of RPMR samples have not been thermally pre-treated and the mass loss of 45% occurs between 290 and 300^{0}C. This curve reveals the appearance of three distinct mass loss regions. The first loss (7.5%), between 30 and 280^{0}C, is attributed to the removal of superficial water molecules or water from the solid pores. At second mass loss the material get thermally degraded and get sintered. Thus, the bricks made out of RPMR can withstand maximum of 300^{0}C.

SEM images (Figure 4) for RPMR clearly indicate the presence of irregular pores and fibrous nature. The RPMR holds the moisture in these pores and the fibrous envelops providing obstacle for moisture to move towards the surface. Fibrous nature gives very high energy absorbing ability and hence the high compressive strength.

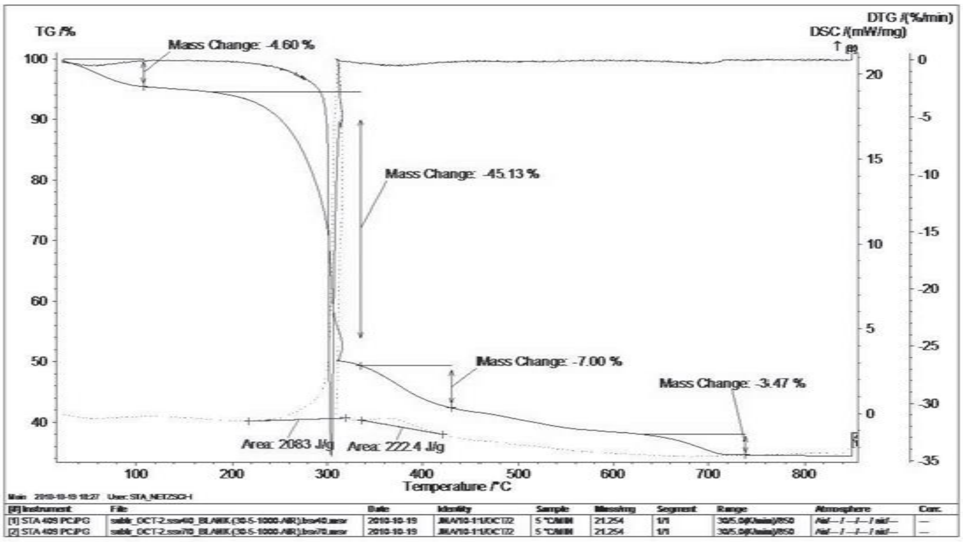

Figure 3: TG-DTA of RPMR

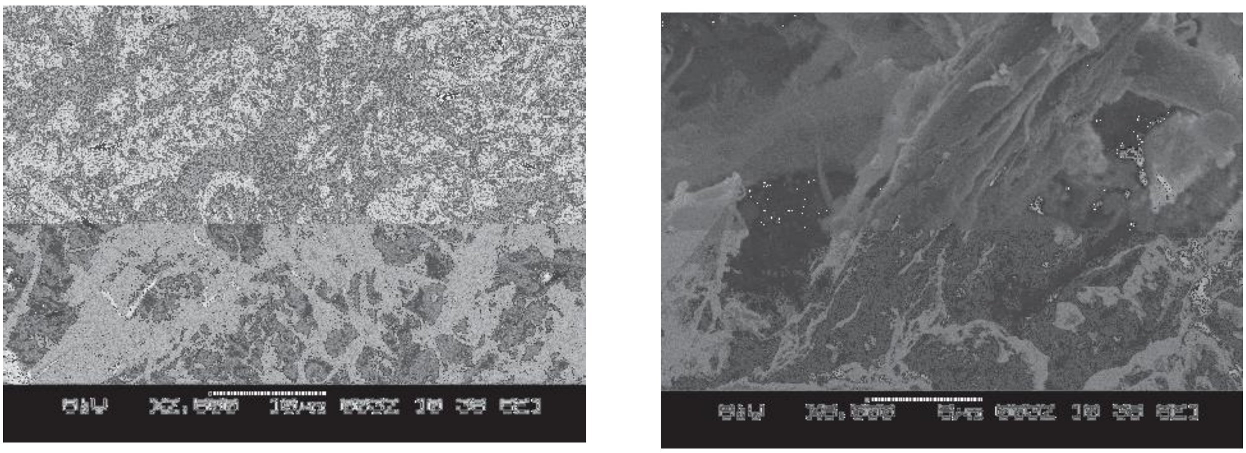

Figure 4: SEM Monograph of Virgin RPMR Sample

4.2. BRICK ANALYSIS

Table 5 shows the averaged test results obtained from the tests. Three brick samples of each of C0, C5, C10, C15, and C20 with dimensions of 230x105x80 mm^3 were used for the compressive strength. Another three samples each with same dimensions were tested for the specific weight, water absorption and efflorescence. All of these tests were conducted in accordance with Indian standards.

The obtained test results show that the minimum compressive strength requirements in IS 3495:1992 were obtained.

The dry compressive strength of brick samples is determined using UTM. All brick samples shows excellent compressive strength (5±0.5 MPa) as compared to conventional brick (3±0.5 MPa). Because of fibrous nature of the RPMR the brick under compressive load shrunk but did not break. The reported values are the maximum load the UTM can apply on the pulp brick sample. However with change in RPMR-FA-cement composition compressive strength does not change considerably and practically remain constant.

Because of high voidage and cellulosic nature of RPMR the water absorption is directly proportional to RPMR content. Water absorption increases by almost 40% (by mass). The percentage water absorbed can be reduced by applying water proof coating over the brick surface.

Table 5: Brick Testing Results

Sample	Compressive Strength (MPa)	Water Absorption (%)	Density (kg/m^3)	Efflorescence
Burnt Clay Bricks	3.1	14.12	1695	Nil
Fly Ash Bricks	3.12	14.64	1750	Nil
C0	4.44	65.3	1176	Nil
C5	4.78	63.4	1043	Nil
C10	5.12	60.7	885	Nil
C15	5.2	58.64	853	Nil
C20	5.6	56.23	846	Nil

6. CONCLUSIONS

The physico-mechanical properties of brick samples with paper pulp fly ash and cement as a binder are investigated. The test results show that the RPMR-FA-cement combination provides results which can be potentially used in the production of lighter and economical new brick material. The observations during the tests show high energy absorption capacity even beyond the failure load. This composition produces brick which weigh half of that of the conventional clay bricks. The observations during the tests show that bricks with the of 30% fly ash and 20% addition of cement to 50% RPMR exhibits a compressive strength of 5.6 MPa which is almost two times greater than the conventional clay bricks (3.1Mpa) and satisfies the requirements of IS 1077 for a building material to be used in the indoor structural applications. These bricks under pressure shrink but do not exhibit sudden brittle fracture even beyond the failure loads and indicate high energy absorption capacity by allowing lower manufacturing cost. The developed waste create bricks is recommended for the construction of low cost affordable housing. The present experimental study for the design and development of waste create bricks using industrial solid waste is useful to provide a potential sustainable solution.

7. ACKNOWLEDGEMENT

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