AN INVESTIGATIONAL STUDY ON USE OF WASTE MATERIALS IN ECO-FRIENDLY FLY ASH BRICKS

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ABSTRACT

Conventional bricks are produced from clay whereas fly ash bricks make use of fly ash, sand and cement.Due to rising demand the quarrying operation for sand and clay has increased. Also the need for cement has increased which has led to high emission of CO_2 gas and its high prices. In this study saw dust, sugar bagasse ash, saw dust ash and rice husk ash has been used as a partial replacement for cement whereas rubber tyre, thermocol, cocopeat, plastic powder and coconut shell ash has been used as a replacement for sand. Engineering property such as compressive strength has been studied at 14 days. From the study, it has been observed that sugar bagasse ash and saw dust ash can be used for partial replacement of cement and rubber tyre, plastic powder and coconut shell ash can be used as a replacement for sand. In the entire study there has been no use of clay as well as sand whereas an optimum quantity of cement has been used.

Keywords

CSA-coconut shell ash, RHA-rice husk ash, SBA-sugar bagasse ash, SDA-saw dust ash, SCM-supplementary cementitious material, OPC- ordinary portland cement.

1. INTRODUCTION

One of the oldest building and construction material which is being used today is brick. Long back ago in 8000 BC the first dried clay bricks were used and later in early 4500 BC the fired clay bricks were adopted.[1,2] The worldwide annual production of bricks is currently about 1391 billion units and the demand for bricks is expected to be continuously rising [3,4]. It is estimated that India has more than 100,000 brick kilns producing about 250 billion bricks annually, employing about 15 million workers and consuming about 35 million tons of coal annually. It is alarming to note that 300 mm depth of fertile top soil in India will be consumed for burnt clay brick production in about 60 years[5].Conventional bricks are produced from clay with high temperature kiln firing or from ordinary Portland cement (OPC) concrete. Quarrying operations for obtaining the clay are energy intensive, adversely affect the landscape, and generate high level of wastes. Also the use of cement in bricks is increasing the demand for cement which accounts for carbon footprints. Production of 1kg of cement accounts for emission of 1 kg of CO_2 and require 1.5 Kwh of energy. Worldwide production of OPC is responsible for about 7% of all CO_2 generated [3]. Hence there is a need to reduce the percentage of cement and replace it by SCM such as sugar bagasse ash, saw dust ash as well as the sand by plastic, rubber or coconut shell ash so as to conserve the natural resources, solve the problem of disposal of waste materials, thus developing eco-friendly bricks with low cost and high durability.

2. RESEARCH METHODOLOGY

Collection of waste materials from nearby location was done followed by a chemical composition analysis to find out the percentage of various components such as SiO_2, CaO, Al_2O_3 and Fe_2O_3.Based on this the percentage replacement of cement was decided. Depending upon the crushing strength of various materials its use as a replacement for sand was decided. Then casting of the bricks with various compositions was done and their compressive strength at 14 days (water curing) were found out. Based on the results obtained, decision for use of waste material as a replacement for sand and cement was taken.

3. MATERIALS

Materials used during this experimental study are listed below

3.1 Cement (OPC)

Cement is binder that is widely used in construction because of its adhesive and cohesive properties. It provides a binding medium for the ingredients of bricks. Portland cement is a type of cement that is commonly used in construction. It is made from a combination of argillaceous and calcareous materials to a partial fusion at about 1450 °C. The argillaceous materials are clay, slate, shale and selected blast-furnace slag. The calcareous materials are usually chalk and limestone.

3.2 Fly ash

Fly ash, also known as "pulverized fuel ash" in the United Kingdom, is a coal combustion product that is composed of the particulates (fine particles of fuel) that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of the boiler is called bottom ash. Class F fly ash has been used for the study. The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 7% lime (CaO).

3.3SawDust

Sawdust or wood dust is a by-product or waste product of woodworking operations such as sawing, milling, planning, routing, drilling and sanding.

3.4 Saw Dust Ash

The sawdust is converted into Sawdust briquette which is used as a fuel in heating of boiler. When this by product is ignited we get saw dust ash.

Table 1. Chemical composition of saw dust ash

Saw dust Saw dust briquette Saw dust ash

Figure 1.

Percentage composition (%)		
Oxide	**SDA**	**OPC**
SiO_2	62.87	20.70
Al_2O_3	9.85	5.75
Fe_2O_3	4.45	2.50
CaO	10.35	64.0
MgO	4.18	1.00

3.5 Rice Husk Ash

Rice husk is the outermost part of rice paddy, it covers about 20 to 25 % of the rice weight. RHA is a SCM and being studied in a past few decades to replace cement through its pozzolanic properties. RHA is obtained from raw rice husk changed into ash by combustion method to remove volatile organic carbon such as cellulose and lignin.

3.6 Sugar Bagasse Ash

Sugarcane bagasse is a byproduct of sugar factories and is used as a fuel which produces sugar bagasse ash. The disposal of this material is already causing environmental problems around the sugar factories. So, it can be used as a cementitious material.

Figure 2. Sugar Bagasse

Figure 3. Sugar bagasse ash

Table 2. Chemical composition of sugar bagasse ash

Percentage composition (%)		
Oxide	**SBA**	**OPC**
SiO_2	65	20.70
Al_2O_3	2.98	5.75
Fe_2O_3	8.98	2.50
CaO	12.21	64.0
MgO	0.62	1.00

3.7 Thermocol

Thermocol is another name for Polystyrene, it's a synthetic aromatic (benzene derivative) polymer made from the monomer styrene (a monomer is a molecule that may bind chemically to other molecules to form a polymer. Hence the name Polystyrene). It can be either solid, or foam like (Styrofoam!), and because of its resilience is often used in protective packaging - CD and DVD cases, and Styrofoam peanuts. It is most assuredly not environmentally friendly, it doesn't degrade for hundreds of years, and is resistant to photolysis. For project work thermocol used for packaging purpose was grinded into powder and was used.

3.8 Cocopeat

Cocopeat is a natural fibre made of coconut husks. The extraction of the coconut fibre from husks gives us this by-product called cocopeat.

Figure 4. Cocopeat

3.9 Crushed Tyre Rubber

Waste or Scrap tires, also known as End-of-Life Tires (ELT), are used rubber tires that because of their abrasion state are not safe for public traffic. Waste tires can go into tire recycling or will be dumped, either in legal landfills or illegally; another portion may be pyrolysed to produce tire-derived fuel or heat energy. Unrecycled tire waste is an enormous global problem because of their non-biodegradability, their flammability and their chemical composition that leads to leaching of toxic substances into the ground on dumping and hazardous fumes on incineration.

3.10 Coconut Shell Ash

Coconut shell is an agricultural waste and is available in plentiful quantities throughout tropical countries worldwide. Coconuts are produced in 92 countries worldwide on about more than 10 million hectares. Indonesia, Philippines and India account for almost 75% of world coconut production with Indonesia being the world's largest coconut producer. The major advantage of using coconut biomass as a fuel is that coconut is a permanent crop and available round the year so there is constant whole year supply.

Figure 5. Coconut shell **Figure 6. Coconut shell ash**

Table 3. Chemical composition of coconut shell ash

	Percentage composition (%)	
Oxide	**CSA**	**OPC**
SiO_2	37.97	20.70
Al_2O_3	24.12	5.75
Fe_2O_3	15.48	2.50
Cao	4.98	64.0
MgO	1.89	1.00

3.11 Plastic

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications. It is produced via chain-growth polymerization from the monomer propylene.Polypropylene belongs to the group of polyolefins and is partially crystalline and non-polar. Its properties are similar to polyethylene, but it is slightly harder and more heat resistant. It is a white, mechanically rugged material and has a high chemical resistance. Polypropylene is the second-most widely produced commodity plastic (after polyethylene) and it is often used in packaging and labeling. In 2013, the global market for polypropylene was about 55 million tones .

Figure 7. Raw material

Figure 8. Plastic powder

4. RESULT

The compressive strength test was carried out according to IS 3495 (Part 1). The sample cubes with the dimension of 230mm × 110 mm × 70 mm were tested. The sample cubes were cured in water and tested for compressive strength at the curing age of 14 days. The compressive strength average was taken from the result of three sample cubes. A minimum compressive strength of 3.5 N/mm^2 is required as per IS 12894: 2002.The bricks are classified into different classes according to the following table given in IS 12894: 2002.

Table 4. Classes of Pulverized Fuel Ash-Lime Bricks

Class designation	**Average wet compressive strength not less than**	
	N/mm2	kg f/cm2 (Approx.)
30	30.0	300
25	25.0	250
20	20.0	200
17.5	17.5	175
15	15.0	150
12.5	12.5	125
10	10.0	100
7.5	7.5	75
5	5.0	50
3.5	3.5	35

4.1 Case I

Composition: - Fly ash, saw dust, coconut shell ash, and cement.

Table 5. Result table for CSA as a replacement for sand and saw dust as a SCM for cement

Sr.no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	25300	61.22	2.612	2.42
2	Brick 2	25300	70.00	2.698	2.77
3	Brick 3	25850	61.10	2.578	2.36
4.	Average	25483.333	64.107	2.629	2.517

Self-weight to compressive strength ratio = 1.044 $kgmm^2/N$

This brick composition does not satisfy the minimum requirement of compressive strength. Hence Saw Dust cannot be used as a supplementary cementitious material.

4.2 Case II

Composition: - Fly ash, sugar bagasse ash, coconut shell ash and cement.

Table 6. Result table for CSA as a replacement for sand and SBA as a SCM for cement

Sr.no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	26450	141.20	2.875	5.34
2	Brick 2	25300	122.50	2.745	4.84
3	Brick 3	25300	120.20	2.638	4.75
4	Average	25683.333	127.967	2.753	4.977

Self-weight to compressive strength ratio = 0.553 $kgmm^2/N$

This brick composition can be allocated a Class Designation "5" as per Table 4. Hence Sugar Bagasse Ash can be used as a supplementary cementitious material.

4.3 Case III

Composition: - Fly ash, saw dust ash, coconut shell ash and cement.

Table 7. Result table for CSA as a replacement for sand and SDA as a SCM for cement

Sr.no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	25300	401.50	2.661	15.87
2	Brick 2	26450	420.00	2.746	15.88
3	Brick 3	25850	398.46	2.224	15.41
4	Average	25866.667	406.653	2.544	15.720

Self-weight to compressive strength ratio = 0.161 $kgmm^2/N$

This brick composition can be allocated a Class Designation "15" as per Table 4. Hence Saw Dust Ash can be used as a supplementary cementitious material.

4.4 Case IV

Composition: - Fly ash, rice husk ash, coconut shell ash and cement.

Table 8. Result table for CSA as a replacement for sand and RHA as a SCM for cement

Sr.no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	25300	41.50	2.561	1.640
2	Brick 2	25300	48.00	2.646	1.897
3	Brick 3	25850	35.50	2.424	1.373
4	Average	25483.333	41.667	2.544	1.673

Self-weight to compressive strength ratio = 1.520 $kgmm^2/N$

This brick composition does not satisfy the minimum requirement of compressive strength. Hence Rice Husk Ash cannot be used as a supplementary cementitious material.

4.5 Case V

Composition: - Fly ash, coconut shell ash and cement.

Table 9. Result table for CSA as a replacement for sand

Sr. no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	25300	137.62	2.836	5.439
2	Brick 2	26450	152.75	2.875	5.775
3	Brick 3	25300	159.20	2.786	6.292
4	Average	25683.333	149.857	2.832	5.835

Self-weight to compressive strength ratio = 0.485 $kgmm^2/N$

This brick composition can be allocated a Class Designation "5" as per Table 4. Hence Coconut Shell Ash can be used as a substitute to sand in bricks.

4.6 Case VI

Composition: - Fly ash, plastic and cement.

Table 10. Result table for Plastic as a replacement for sand

Sr.no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	25300	229.68	2.716	9.078
2	Brick 2	26450	243.85	2.875	9.219
3	Brick 3	25300	225.14	2.794	8.898
4	Average	25683.333	232.890	2.795	9.065

Self-weight to compressive strength ratio = 0.308 $kgmm^2/N$

This brick composition can be allocated a Class Designation "7.5" as per Table 4. Hence Plastic can be used as a substitute to sand in bricks.

4.7 Case VII

Composition: - Fly ash, thermocol and cement.

Table 11. Result table for thermocol as a replacement for sand

Sr.no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	24380	26.25	1.654	1.076
2	Brick 2	25760	25.00	1.429	0.970
3	Brick 3	25300	21.62	1.566	0.854
4	Average	25146.667	24.290	1.550	0.967

Self-weight to compressive strength ratio = 1.602 $kgmm^2/N$

This brick composition does not satisfy the minimum requirement of compressive strength. Hence Thermocol cannot be used as a substitute for sand replacement.

4.8 Case VIII

Composition: - Fly ash, cocopeat and cement.

Table 12. Result table for Cocopeat as a replacement for sand

Sr.no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	24840	79.40	2.645	3.19
2	Brick 2	25300	88.62	2.734	3.50
3	Brick 3	25300	89.93	2.776	3.55
4	Average	25146.667	85.983	2.718	3.413

Self-weight to compressive strength ratio = 0.796 $kgmm^2/N$

This brick composition does not satisfy the minimum requirement of compressive strength. Hence Coco Peat cannot be used as a substitute for sand replacement.

4.9 Case IX

Composition: - Fly ash, rubber, cement.

Table 13. Result table for rubber as a replacement for sand

Self-weight to compressive strength ratio = 0.508 kgmm^2/N

Sr. no.	Content	Surface area (mm^2)	Load (KN)	Self-weight (kg)	Compressive strength (N/mm^2)
1	Brick 1	25300	131.75	2.638	5.207
2	Brick 2	25300	126.23	2.549	4.989
3	Brick 3	26450	138.32	2.661	5.229
4	Average	25683.333	132.100	2.616	5.142

This brick composition can be allocated a Class Designation "5" as per Table 4. Hence Rubber can be used as a substitute for sand replacement.

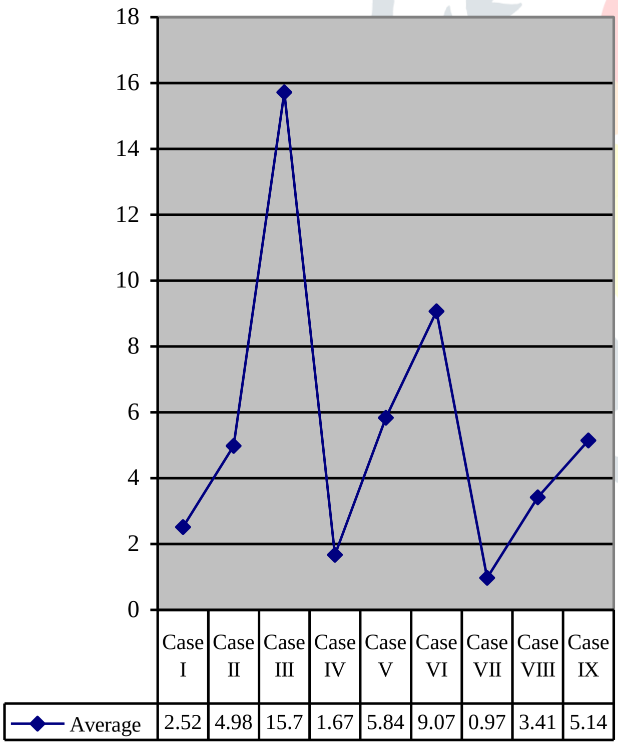

Figure 9. Graph of compressive strength w.r.t. various composition cases.

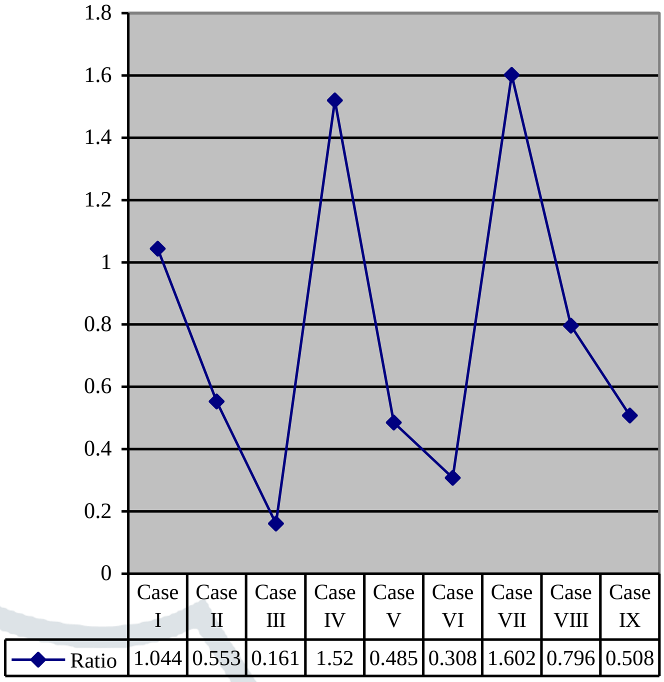

Figure 10. Graph of self-weight to compressive strength ratio w.r.t. various composition cases.

Figure 11. Process of brick casting

5. CONCLUSION

1. Saw dust ash and sugar bagasse ash can be used as a supplementary cementitious material.

2. Coconut shell ash, rubber and plastic can be used as a replacement for sand.

3. Bricks with high compressive strength are obtained.

4. Conservation of natural resources like clay and sand.

5. A solution for disposal of waste materials is found out.

6. Enhancing the use of waste materials as an industrial fuel.

7. As SCM's are used there is a percentage reduction in use of cement and hence a reduction in emission of CO_2 gas to a certain extent has been achieved.

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