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### An Experimental Study on Physical Characteristics of Eco-Friendly blocks

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**ABSTRACT:** This paper presents an experimental investigation carried out on eco-friendly blocks having various percentage of fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag. Raw materials are added to the pan mixer with different mix proportions and are mixed thoroughly with water until a homogeneous mixture is formed. Prepared homogeneous mixture is fed into the press and moulded to a block of size 200 x 200 x 300 mm using vibro-hydraulic press. Moulded blocks are air dried for 24 hours, arranged in stacks and are cured for a period of 28 days by sprinkling the water to achieve the optimum strength. Compressive strength, water absorption, efflorescence, dimension tolerance and density tests are conducted as per BIS codal provisions. Eco-friendly blocks having varying proportions of industrial by-products and less stone dust content satisfy the specifications as per BIS codal provisions and can be used in structures as a sustainable construction material.

**KEYWORDS:** Eco-friendly blocks, Compressive strength, Water absorption, Efflorescence, Dimension tolerance, Density

#### I.INTRODUCTION

In developing countries like India, disposal of solid waste is a serious problem. In order to overcome this threat, recycling and reuse of waste material is critically important for the conservation of environment as well as for sustainable development. Use of waste materials in the production of eco-friendly blocks as an alternative source reduces harmfulness to the environment. Bricks are the important and oldest construction materials because of their reliability, strength, durability and low cost. They are essential for the construction of super structures. Bricks are often used for the reason of economy and speed, even in the areas where stones are abundantly available. Use of solid wastes like fly ash, boiler slag, LD slag in the manufacture of blocks not only ensures sustainable development but also have indirect benefits than the conventional clay bricks. Eco-friendly blocks are commonly used for compound walls, non-load bearing structures. Additives like gypsum, stone dust, boiler slag, LD slag, coarse aggregate and stone dust are some of the additives used for accelerating rate of strength gain in lime—fly ash compacts.

In the present investigation, an attempt has been made to study the physical characteristics of eco-friendly blocks having various percentage of fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag. Performance of eco-friendly blocks in terms of compressive strength, water absorption, efflorescence, dimension tolerance and density tests are conducted as per BIS codal provisions.

#### II. EXPERIMENTAL PROGRAM

#### Materials Used:

Fly Ash: Fly ash is procured fromGrasim Industries Limited, Harihara, Davangeredistrict.
Lime: Lime is procured fromShree Sai Krupa Industries, Mudhol, Bagalkot district.
Gypsum: Gypsum is procured froma local fertilizer shop.
Cement: Ordinary Portland cement of 43 grade conforming to IS 269 (2015) is used.
Stone Dust: Stone dust is procured froma local quarry which is free from impurities.
LD Slag: LD slag is procured fromBMM Inspat Limited, Hospet, Vijayanagara district.
Coarse Aggregate: Coarse aggregate is procured from a local quarry which conforms to IS 383 (2016).
Boiler Slag: Boiler slag is procured fromBMM Inspat Limited, Hospet, Vijayanagara district.

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For the above materials, preliminary tests such as specific gravity and gradation is carried out as per BIS codal provisions viz. IS 2386–Part 1 (1963), IS 2386–Part 3 (1963), IS 4031–Part 11 (1999) and IS 1727 (1967). Table 1 shows the preliminary test results.

SI. No.	Material	Specific gravity	Gradation	
1	Fly Ash	1.93	—	
2	Lime	2.20	—	
3	Gypsum	2.32	_	
4	Cement 2.67		_	
5	Stone dust	2.48	4.75 mm down size	
6	Coarse aggregate	2.7	12 mm down size	
7	Boiler slag	2.6 4.75 mm down size		
8	LD slag 2.74 4.75 mm down		4.75 mm down size	

#### **Table 1: Preliminary test results**

#### **Mix Proportions of Eco-Friendly Blocks:**

Table 2 shows the mix proportions of eco-friendly blocks with varying percentage of fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag considered in the present study.

Table 2: Proportions for various mixes of eco-friendly blocks

Mix ID	Fly ash (%)	Lime (%)	Gypsum (%)	Cement (%)	Stone dust (%)	Coarse aggregate (%)	Boiler slag (%)	LD slag (%)
1	30	10	-	-	50	-	10	-
2	40	10	-	-	30	20	-	-
3	50	10	-	-	40	-	-	-
4	60	10	-	-	20	10	-	-
5	65	10	5	-	-	20	-	-
6	70	10	5	-	15	-	-	-
7	50	-	-	10	20	-	20	-
8	62.5	10	12.5	-	-	-	15	-
9	55	-	-	5	30	-	10	-
10	-	10	-	10	40	-	-	40
11	-	15	-	10	25	10	-	40
12	30	10	-	10	20	10	10	10

#### Mixing:

Raw materials are added to the pan mixer with different mix proportions and are mixed thoroughly with water until a homogeneous mixture is formed. Raw materials should be free from lumps as they may cause cracks in bricks and reduce the strength. The same procedure is followed for different mix proportions.

#### Casting and Curing:

Prepared homogeneous mixture is fed into the press for moulding through a conveyer belt. Moulding of blocks for a size of 200 x 200 x 300 mm is done using vibro-hydraulic press. The moulded blocks are kept on a level ground and air dried for 24 hours. Curing is done for a period of 28 days to achieve the optimum strength by sprinkling the water manually.

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#### Tests on Eco-friendly blocks:

Table 3 shows the various physical tests conducted on eco-friendly blocks as per BIS codal provisions.

SI. No.	Test	Remarks
1	Compression	IS 3495–Part 1 (2019)
2	Water absorption	IS 3495–Part 2 (2019)
3	Efflorescence	IS 3495–Part 3 (2019)
4	Dimension tolerance	Comparing the actual dimensions of length, width and height of blocks with that of mould
5	Density	Ratio of dry weight and volume of block

#### Table 3 : Tests conducted on eco-friendly blocks

#### **III.RESULTS AND DISCUSSION**

#### **Compressive Strength Test Results:**

The compressive strength of eco-friendly blocks after 28 days of curing is graphically represented in Fig. 1.



#### 28 days Compressive strength

#### Fig. 1. 28 days Compressive strength of eco-friendly blocks

Mix 1 having 30% fly ash, 10% lime, 50% stone dust and 10% boiler slag shows less compressive strength and does not conform to IS 12894 (2002). Mixes 7, 9,10,11 and 12 having fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag conform to compressive strength requirements as per IS 2185–Part 1 (2005). Other Mixes viz. 2, 3, 4, 5, 6 and 8 having varying content of fly ash, lime, gypsum, stone dust, coarse aggregate and boiler slag conform to compressive strength requirements as per IS 12894 (2002). High compressive strength value is observed in Mix 12 having 30% FA, 10% lime, 10% cement, 20% stone dust, 10% coarse aggregate, 10% boiler slag and 10% LD slag.

#### Water Absorption Test Results:

Water absorption results of eco-friendly blocks after 28 days of curing is graphically represented in Fig.2.Mix 11 having 15% lime, 10% cement, 25% stone dust, 10% coarse aggregate and 40% LD slag shows minimum water absorption of 2.35%. Mix 1 having 30% fly ash, 10% lime, 50% stone dust and 10% boiler slag shows maximum water

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absorption of 15.96%. Mixes viz. 1, 2, 3, 4, 5, 6 and 8 having varying content of fly ash, lime, gypsum, stone dust, coarse aggregate and boiler slag show water absorption values less than 20% and conform to IS 12894 (2002). Mixes 7, 9, 10, 11 and 12 having fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag show water absorption values less than 10% and conform to IS 2185–Part 1 (2005).



#### Fig. 2. Water absorption of eco-friendly blocks

#### **Efflorescence Test Results:**

Efflorescence testresults of eco-friendly blocks after 28 days of curing is shown in Table 4.

Mix ID	Rating as per IS 3495 – Part 3 (2019)	Remarks
1	Slight	
2	Nil	
3	Slight	
4	Slight	
5	Slight	A per IS 12894 (2002).
6	Slight	rating of efflorescence
7	Slight	should not be more than
8	Slight	"moderate"
9	Slight	
10	Nil	
11	Slight	
12	Slight	

#### Table 4: Efflorescence test results on eco-friendly blocks

As per IS 12894 (2002), rating of efflorescence should not be more than "Moderate". Percentage of white spot in Mix 2 having 40% fly ash, 10% lime, 30% stone dust and 20% coarse aggregate is "Nil". Also Mix 10 having 10% lime, 10% cement, 40% stone dust and 40% LD slag showed no white spot on its surface. In all other mixes, rating of efflorescence is observed to be "Slight".

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#### **Dimension Tolerance Test Results:**

Table 5 shows the dimensions of eco-friendly blocks which are cured for 28 days. All mixes having various proportion of fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag satisfy the limits specified in IS 2185-Part 1 (2005).

Mix ID	Length (mm)	Width (mm)	Height (mm)	Remarks
1	300	199.7	199.8	
2	300	199.9	200	
3	299.7	200	200	
4	300	199.8	200	
5	300	200	199.8	
6	300	199.7	199.9	As per IS 2185–Part 1 (2005), the variation in
7	300	199.8	200	length should not be more than $\pm 5$ mm and variation in width and height should not be more
8	299.6	200	200	than $\pm 3$ mm.
9	300	199.9	200	
10	300	199.7	199.7	
11	300	199.8	200	
12	300	200	199.9	
Mean	299.94	199.86	199.93	

#### Table 5: Dimensions of eco-friendly blocks

#### **Density Test Results:**

Density of Eco-friendly blocks after 28 days of curing is graphically represented in Fig. 3.



#### Density (kg/m<sup>3</sup>)

#### Fig.3. Density of eco-friendly blocks

Mix 11 having 15% lime, 10% cement, 25% stone dust, 10% coarse aggregate and 40% LD slag shows maximum density of 2094.9 kg/m<sup>3</sup>. Mix 1 having 30% fly ash, 10% lime, 50% stone dust and 10% boiler slag shows minimum density of 1473.3 kg/m<sup>3</sup>. Mixes viz. 2, 3, 4, 5, 6 and 8 having varying content of fly ash, lime, gypsum, stone dust, coarse aggregate and boiler slag show density values in the range from 1473.3 kg/m<sup>3</sup> to 1725.8 kg/m<sup>3</sup>. Except Mix 7, all the other mixes i.e. 9,10,11 and 12 having fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag show density values greater than 1800 kg/m<sup>3</sup> and conform to IS 2185–Part 1 (2005).

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#### **IV.CONCLUSIONS**

The present study reports the performance of eco-friendly blocks having various percentage of fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag.Important conclusions drawn are as follows.

- 1. Mix 1 having 30% fly ash, 10% lime, 50% stone dust and 10% boiler slag shows less compressive strength and does not conform to IS 12894 (2002). Other Mixes viz. 2, 3, 4, 5, 6 and 8 having varying content of fly ash, lime, gypsum, stone dust, coarse aggregate and boiler slag conform to compressive strength requirements as per IS 12894 (2002).
- 2. High compressive strength value is observed in Mix 12 having 30% FA, 10% lime, 10% cement, 20% stone dust, 10% coarse aggregate, 10% boiler slag and 10% LD slag. Mixes 7, 9,10,11 and 12 having fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag conform to compressive strength requirements as per IS 2185–Part 1 (2005).
- 3. Mix 11 having 15% lime, 10% cement, 25% stone dust, 10% coarse aggregate and 40% LD slag shows minimum water absorption of 2.35%. Mixes 7, 9,10,11 and 12 having fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag show water absorption values less than 10% and conform to IS 2185–Part 1 (2005).
- 4. Mix 1 shows maximum water absorption of 15.96%. Mixes viz. 1, 2, 3, 4, 5, 6 and 8 having varying content of fly ash, lime, gypsum, stone dust, coarse aggregate and boiler slag show water absorption values less than 20% and conform to IS 12894 (2002).
- 5. No efflorescence traces as white spots are observed in Mix 2 having 40% fly ash, 10% lime, 30% stone dust and 20% coarse aggregate is Nil. Also Mix 10 having 10% lime, 10% cement, 40% stone dust and 40% LD slag showed no white spot on its surface. In all other mixes, rating of efflorescence is observed to be slight as per IS 12894 (2002).
- 6. From dimension tolerance test results, all the mixes having various proportions of fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag satisfy the limits specified in IS 2185–Part 1 (2005).
- From the density test results, Mix 11 shows maximum density of 2094.9 kg/m<sup>3</sup>. Except Mix 7, all the other mixes i.e. 9,10,11 and 12 having fly ash, lime, gypsum, cement, stone dust, coarse aggregate, boiler slag and LD slag show density values greater than 1800 kg/m<sup>3</sup> and conform to IS 2185–Part 1 (2005).
- Mix 1 shows minimum density of 1473.3 kg/m<sup>3</sup>. Mixes viz. 1, 2, 3, 4, 5, 6 and 8 having varying content of fly ash, lime, gypsum, stone dust, coarse aggregate and boiler slag show density values in the range from 1473.3 kg/m<sup>3</sup> to 1725.8 kg/m<sup>3</sup>.

**Concluding Remarks:** Eco friendly blocks having varying proportions of industrial by-products and less stonedust content satisfy compressive, water absorption, efflorescence, dimensional tolerance and density requirements as per BIS codal provisions and can be used in structures as a sustainable construction material.

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