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Techno-Economic Feasibility Study of Stone Dust Fly Ash Cement Bricks over Ordinary Clay Bricks in Affordable Housing

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Abstract:Construction cost in India is increasing approximately by 15% every year , primarily due to increased cost of basic building materials such as bricks, steel, cement, timber etc. & of-course labour. This has led to cost of construction to such level that it has become difficult for persons of low & middle income group to afford a decent house. Therefore there is a need of the hour to make materials more cost effective using local & economic materials which are found in abundance nearby. Fly Ash is a material disposed off as a waste from various thermal plants and if used in the making of fly ash cement bricks shall be very cost effective and technically sound. The Affordable housing policy, wherein the houses/flats are to be provided to economically weaker section at an affordable price with the application of efficient material, finance & technology is implemented by various states, particularly in Rajasthan lot of initiative has taken place by the Government & private developers. In Rajasthan various projects of Affordable housing are being constructed . Stone dust ,available from various stone crushing plants (considered to be waste) which is also available in abundance in Rajasthan ,if mixed with fly ash & cement ,can be used in making non conventional bricks ,which has proven to be a better alternative to conventional clay bricks functionally, economically & technologically. Various tests have been performed to ascertain different parameters to conclude that fly ash Stone dust Cement bricks are much feasible techno-economically.

Key Words: Fly Ash, Stone Dust, Cement, Clay Bricks, Affordable Housing, Water Absorption, Compressive Strength

Introduction

Fly ash is produced as a byproduct in thermal plants and the proper use of it is still a challenge in spite of various mandatory measures being adopted. Fly ash utilization in the country has remained less than 30% during the past 5 years and it might take several years to reach the final goal of cent percent utilization. It is estimated at present nearly 160 million ton fly ash is produced every year, out of which hardly 40-50 % is used in all possible applications .Fly Ash brick is being considered as one of the best uses of fly ash.

Normally Fly ash is used in ordinary clay bricks to improve some of its properties. In Rajasthan, India Stone Dust is available in abundance at Stone crushers and the disposal of which is also of much concern. To utilize the stone dust & Fly Ash in brick manufacturing, they are mixed with cement to prepare brick shaped blocks in following proportion

Stone dust-64%, Fly Ash-30%, OPC Cement-6%

It has to be seen whether the use of fly ash & Stone Dust in brick manufacturing industry is techno-economically viable, if utilized by application of optimum technologies, which are available with commensurate levels of automation and capacity generation. Fly ash brick manufacturing is a potential field of application wherein large-scale utilization of fly ash is possible.

In this particular project it has to be ascertained & understood that whether fly ash Stone dust cement bricks are better alternative to conventional burnt clay bricks in structural, functional and economic aspects. This industry has the potential to consume at least 50% of the ash production in India. By use of this application we can convert waste into wealth

Methodology:

Fly Ash Stone Dust Cement Bricks Manufacturing Process:

Fly ash, stone dust and cement are manually fed into a pan mixer where water is added in the required proportion for intimate mixing.

The proportion of the raw materials is taken in the ratio 64% of stone dust, 30% of fly ash , 6% cement and water.

The materials are mixed in pan mixture. After mixing, the mixture is conveyed through belt conveyor to the hydraulic/mechanical presses. The homogenised mortar taken out of roller mixer is put into the mould boxes. The product is compacted under vibration / hydraulic compression etc. The green bricks are then dried up under sun for 48 hours, .The dried up bricks are stacked and

subjected for water spray curing once or twice a day, for 7-21 days, depending on ambience.

Testing of Bricks

Standard Clay Bricks & Fly Ash Stone Dust Bricks are tested separately for Dimensions, Water Absorption & Compressive Strength and the results are compared for suitability

TESTING OF STANDARD CLAY BRICKS

Measurement of Dimensions of Brick
Determination of Water Absorption
Determination of Compressive Strength

TESTING OF CLAY BRICKS
Taken some sample conventional clay bricks from the site plant located at site Chaksu, Jaipur to conduct few experiments on it to compare with the quality of Stone dust fly ash cement bricks. The experiments and result are explained below

MEASUREMENT OF DIMENSIONS OF BRICK:
For the bricks' dimensions measurement, the procedures were based on Clause 5.2.1, IS 12894:2002. The required apparatus in this test was measuring tape.

In this test, a total of 10 bricks were selected randomly from the bricks stack. Any blister, small projections or loose particles of clay that adhered to each brick were removed. The bricks were then placed in contact with each other in a straight line upon a level surface. The method of arranging the bricks depended on which dimension to be measured; length, width or height. The Figures below shows the arrangement of bricks with respect to the dimension to be measured.

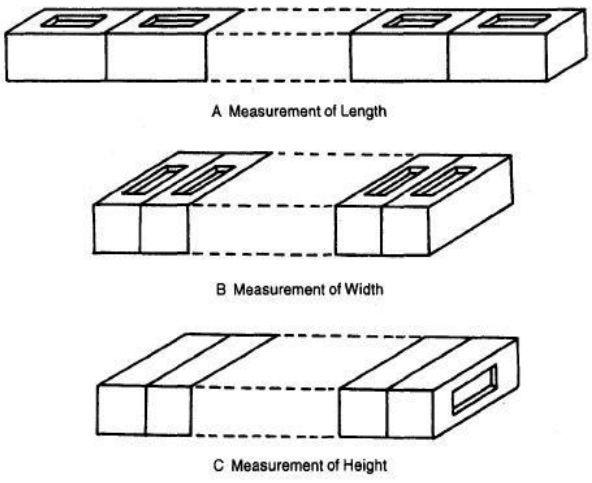

Fig.1 Arrangement of bricks for measurement of (a) length, (b) width, and (c) height

The overall length of the assembled bricks were measured with a steel tape sufficiently long to measure the whole row at one stretch.

Dimensions	Total Measurement for 10 Bricks (mm)	Mean Measurement for Single Brick (mm)
Length, L	2110	211
Width, W	1010	101
Height, H	750	75

Table 1: The results obtained from the measurement of 10 bricks

From the measurement done on 10 bricks, the total length, width and height obtained were 2110 mm, 1010 mm and 750 mm respectively.

By taking the mean for the dimensions of a single brick, a brick was 211mm in length, 101mm in width and 75 mm in height

DETERMINATION OF WATER ABSORPTION
(24-hour Immersion Cold Water Test)

APPARATUS:

A sensitive balance capable of weighing within 0.1 percent of the mass of the specimen and a ventilated oven

PRECONDITIONING:

Dried the specimen in a ventilated oven at a temperature of 105 to 115 °C till it attains substantially constant mass. Cooled the specimen to room temperature and obtained its weight (M1).

PROCEDURE:

Immersed completely dried specimen in clean water at a temperature of 27 ± 2 °C for 24 hours.
Removed the specimen and wiped out any traces of water with a damp cloth and weighed the specimen. Completed the weighing 3 minutes after the specimen has been removed from water (M2). Water absorption, percent by mass, after 24-hour immersion in cold water is calculated by the following formula

$$\frac{M2 - M1}{M1} \times 100$$

Sample	Weight (dry) gm	Weight (wet, after 24 hr) gm	% of water absorption
W-1	2704	3011	11.36
W-2	2707	3018	11.52
W-3	2683	2975	10.89
W-4	2677	2953	10.32
W-5	2753	3049	10.72
		Average	10.94%

Table 2. From the result average % of water absorption is 10.94%.

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DETERMINATION OF COMPRESSIVE STRENGTH OF CLAY BRICKS

APPARATUS:
Compression Testing Machine, Measuring Tape , Surface Grinder, Plywood Sheets.

PROCEDURE:

Preparation of Sample:-

(i) Removed any unevenness observed in the bed faces to provide two smooth and parallel faces by grinding.
(ii) Immersed the sample in water at room temperature for 24 hours.
(iii) Prepared cement mortar (1:1) and filled the frog and all voids in bed faces with it.
(iv) Stored the sample prepared in (iii) under damp jute bag for 3 days in clean water.
(v) Removed and wiped out any trace of moisture.
(vi) Measured the area of two horizontal faces.

Testing:-

$$\text{Compressive Strength (N/mm2)} = \frac{\text{Maximum load at failure in N}}{\text{Avg. Area of bed faces in mm 2}}$$

OBSERVATION TABLE:

Material Test Report

Test For Compressive Strength(N/mm^2) For Red Clay Bricks

S.NO	Sample	Specimen Size of bricks	Avg. Area of bed surfaces (mm^2)	Max load at failure (KN)	Compressive Strength(N/mm^2)
1	W-1	210×101×75mm	21210	309	14.61
2	W-2	211×102×74mm	21522	329	15.33
3	W-3	212×102×73mm	21624	299	13.87
4	W-4	210×100×75mm	21000	309	14.76
5	W-5	211×101×76mm	21311	320	15.02
Average					14.652

Table 3. From the result average compressive strength is 14.652 N/mm2

TESTING OF STONE DUST FLY ASH CEMENT BRICKS

Measurement of Dimensions of Brick
Determination of Water Absorption
Determination of Compressive Strength

TESTING OF FLY ASH STONE DUST CEMENT BRICKS

Few samples of Stone dust fly ash Bricks from bricks plant located at site Chaksu, Jaipur were taken to conduct few experiments on it to justify the quality of Stone dust fly ash bricks. The experiments and results are explained below

MEASUREMENT OF DIMENSIONS OF BRICK:
For the bricks‘ dimensions measurement, the procedures were based on Clause 5.2.1, IS 12894:2002. The required apparatus in this test was measuring tape.

In this test, a total of 10 bricks were selected randomly from the bricks stack. Any blister, small projections or loose particles of clay that adhered to each brick were removed. The bricks were then placed in contact with each other in a straight line upon a level surface. The method of arranging the bricks depended on which dimension to be measured; length, width or height. The Figures below shows the arrangement of bricks with respect to the dimension being measured.

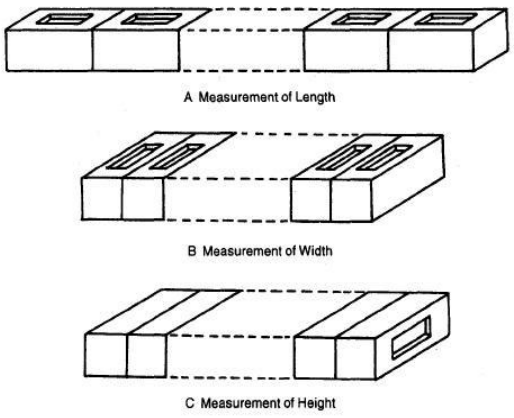

Fig.2. Arrangement of Stone dust fly ash cement bricks for measurement of (a) length, (b) width, and (c) height

The overall length of the assembled bricks (10 Nos in a row) is measured with a steel tape sufficiently long to measure the whole row at one stretch.

Dimensions	Total Measurement for 10 Bricks (mm)	Mean Measurement for Single Brick (mm)
Length, L	2330	233

International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3, Issue No.1 pp : 63-69 1 Jan 2014

Width, W	1040	104
Height, H	750	75

Table 4.: The results obtained from the measurement of 10 bricks

From the measurement done on 10 bricks, the total length, width and height obtained were 2330 mm, 1040 mm and 750 mm respectively.

By taking the mean for the dimensions of a single brick, a brick was 233mm in length, 104 mm in width and 75 mm in height

DETERMINATION OF WATER ABSORPTION
(24-hour Immersion Cold Water Test)

APPARATUS:
A sensitive balance capable of weighing within 0.1 percent of the mass of the specimen and a ventilated oven

PRECONDITIONING:
Dried the specimen in a ventilated oven at a temperature of 105 to 115 °C till it attains substantially constant mass. Cooled the specimen to room temperature and obtain its weight (M1).

PROCEDURE:
Immersed completely dried specimen in clean water at a temperature of 27 ± 2 °C for 24 hours.
Removed the specimen and wiped out any traces of water with a damp cloth and weighed the specimen. Completed the weighing 3 minutes after the specimen has been removed from water (M2). Water absorption, percent by mass, after 24-hour immersion in cold water is given by the following formula

$$\frac{M2 - M1}{M1} \times 100$$

Sample	Weight (dry) gm	Weight (wet, after 24 hr) gm	% of water absorption
W-1	3100	3232	4.26
W-2	3110	3258	4.79
W-3	3175	3331	4.94
W-4	3101	3235	4.35
W-5	3109	3268	5.12
		Average	4.692%

Table 5: From the result average % of water absorption is 4.692 %.

WATER ABSORPTION TEST RESULTS

Sample	Water Absorption in %		
	7 Days	14 Days	21 Days
Fly ash 5%	9.88	7.54	6.36
Fly ash 10%	8.28	7.09	7.40
Fly ash 15%	7.74	6.47	5.99
Fly ash 20%	7.16	6.45	5.97
Fly ash 25%	6.01	6.80	5.45
Fly ash 30%	5.26	4.95	4.69

Table 6. **WATER ABSORPTION TEST RESULTS**

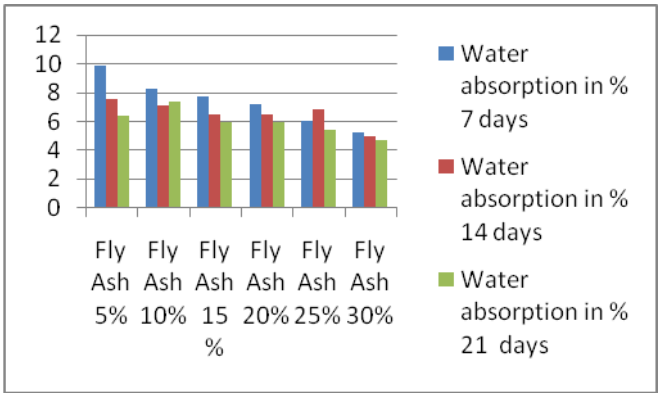

Fig 3. : Water absorption graph at 7, 14, 21 days

DETERMINATION OF COMPRESSIVE STRENGTH OF STONE DUST FLY ASH CEMENT BRICKS

APPARATUS:
Compression Testing Machine, Measuring Tape , Surface Grinder, Plywood Sheets.

PROCEDURE:
Preparation of Sample:-

(i) Removed any unevenness observed in the bed faces to provide two smooth and parallel faces by grinding.
(ii) Immersed the sample in water at room temperature for 24 hours.
(iii) Prepared cement mortar (1:1) and filled the frog and all voids in bed faces with it.
(iv) Stored the sample as prepared in (iii) under damp jute bag for 3 days in clean water.
(v) Removed and wiped out any trace of moisture.
(vi) Measured the area of two horizontal faces.

Testing:-

Compressive Strength (N/mm2) = $\frac{\text{Maximum load at failure in N}}{\text{Aveg.Area of bed faces in mm 2}}$

OBSERVATION TABLE:

Material Test Report

S.NO	Sample	Specimen Size of fly ash bricks	Aveg.Area of bed surfaces(mm^2)	Max load at failure (KN)	Compressive Strength(N/mm^2)
1	W-1	232×103×7	23896	447	18.74

		5mm			
2	W-2	234×104×74mm	24336	426	17.54
3	W-3	233×104×74mm	24232	409	16.88
4	W-4	232×105×75mm	24360	445	18.27
5	W-5	233×103×74mm	23999	463	19.31
Average					18.148

Table 7.: Test For Compressive Strength (N/mm^2) For Stone dust fly ash cement Bricks

From the result average compressive strength is 18.148N/mm2 which is higher than normal clay bricks

COMPRESSIVE STRENGTH TEST RESULTS

Sample	Compressive strength (N/mm^2)		
	7 Days	14 Days	21 Days
Fly ash 5%	8.01	8,82	9.64
Fly ash 10%	10.64	12.01	12.65
Fly ash 15%	14.24	14.67	15.01
Fly ash 20%	15.63	16.12	16.21
Fly ash 25%	15.84	16.62	17.45
Fly ash 30%	16.50	17.74	18.14

TABLE 8.: COMPRESSIVE STRENGTH TEST RESULTS

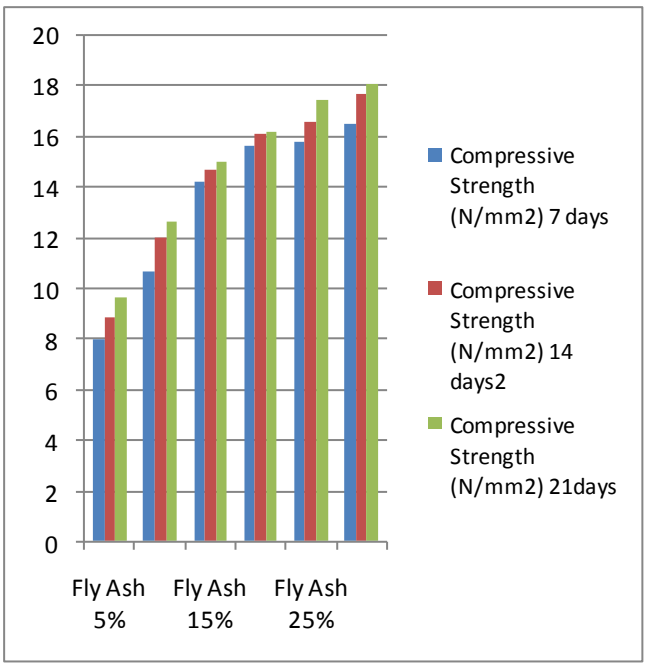

Fig 4. : Compressive strength graph at 7, 14, 21 days

CONCLUSION:

The following results were obtained based on the experiments done

	Stone dust fly ash cement brick	Conventional clay bricks.
Compressive strength	18.148 N/mm^2	14.652 N/mm2
% Water absorption	4.692%	10.94%.

The results show that the Stone dust fly ash Cement bricks have more compressive strength & less water absorption in comparison to conventional clay bricks. Also the cost of making the Stone dust fly ash brick is Rs 3.00 per piece whereas in the market the average price of conventional clay brick is Rs 3.50(though it varies frequently due to season & demand) .Therefore it is ascertained that Stone dust fly ash bricks are more safe, economical and having higher strength compare to conventional clay bricks.
Characteristic comparison of Stone Dust fly ash cement bricks and ordinary red clay bricks is also shown in table below.

ISSUE	STONE DUST FLY ASH CEMENT BRICK	BURNT CLAY BRICK
Manufacturing Process	Machine Moulding	Hand Moulding
Hardening	Air and water curing	Air drying and burning
Size and finish	Smooth and uniform	Un-uniform
Dry density	1500	1800
Cold crushing strength	75-250	30-80
Water absorption %	<10%	Upto 20%
Handling Breakage	1-2	12-15
Efflorescence	Nil	Moderate
Durability	Better	Moderate
Water seepage	Almost nil	Moderate
Resistance salinity	Good	Poor
Fuel	No fuel require	8-20 Tonnes of coal required for sintering one lac bricks
Emission of gases in manufacturing	No emission in manufacturing of bricks	Emission of 0.25 ton of Co_2 1000 bricks
Economics...	a) Lesser handling breakage b) Lesser mortar required c) More quantity can be transported due to lesser density d) Plaster not needed or saves over 30% plastering material	

Loss of soil / Agriculture land	Nil	For brick size of 9"x4"x3" : Loss of Soil – 1770 m3 per million of bricks per annum; and Loss of Land – 0.116 hectare per million of bricks per annum.
Solid Waste Generation and its disposal	Negligible	Ash and un burnt coal from kiln which varies from 25%-40% as per ash content in the coal; Some of this coal-ash is used for covering the bricks in kiln for thermal insulation; and Excess ash is disposed off haphazardly.

Table 9: Comparison of Stone dust fly ash bricks and burnt clay bricks

Therefore Stone dust fly ash cement bricks have many advantages like

- Light weight
- Economical
- Environmental friendly
- Saving of fertile land, pure water
- More compressive strength
- Use of wastage etc.

Thus, stone dust fly ash cement brick is one of the best uses of stone dust & fly ash. It may be concluded that the use of stone dust & fly ash in brick manufacturing industry is techno-economically viable, if utilized by application of optimum technologies, which are available with commensurate levels of automation and capacity generation. Stone dust Fly ash brick manufacturing is a potential field of application wherein large-scale utilisation of stone dust & fly ash is possible.

It can therefore be concluded that stone dust fly ash cement bricks are better alternative to conventional burnt clay bricks in structural, functional and economic aspects and can fulfil the objectives of affordable housing .This industry has the potential to consume at least 50% of the ash production in India & all the stone dust waste material.

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