Importance of Cement Based Unfired Building Blocks in Construction

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Abstract*: *The need of sustainable and low cost building material is one of the prime concerns for the researchers. This is due to ever increasing demand of conventional building materials that are dependent to natural resources. Conventional clay bricks are one of the important building materials for construction industries. Superior engineering properties of clay bricks makes it most preferable building material for making non-structural elements. Production of conventional bricks is dependent to natural resources like clay, river sand and dirt and exploration of such resources is always harmful for environment. The manufacturing process of conventional bricks is fuel consuming and also emits greenhouse gases in bulk. This research focuses towards promoting cement based unfired building blocks along with the use of conventional clay bricks. Review of researches shows that the use of non-biodegradable abundantly available wastes such as fly ash, brick waste or debris, quarry dust, gypsum etc., in the form of fillers for cement based building blocks, provides the best solution to minimize the load bear by conventional clay bricks.

***Keywords*:** Clay bricks, Cement based building blocks, Fillers, Non-biodegradable waste, Fly ash, Brick waste, Quarry dust.

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I. INTRODUCTION

Bricks are one of very important building material used in residential as well as in industrial construction. In general two types of bricks are available for construction with parent materials as clay and cement [1]. Clay bricks are also known as conventional bricks contain silica, alumina, lime, iron oxide and magnesia. Following constituent offers high compressive strength and durability after proper drying and heating of the blocks [1].Cement based bricks are made up of mortar having main constituent as cement, sand and dirt. These bricks are found easier and cheaper in manufacturing also required low maintenance with huge production ability. Cement based bricks not required any heating to get matured except dry and wet curing and that's the main advantage of it.

Manufacturing of conventional bricks are depends on natural resources and world is facing scarcity of the same. Main ingredient like clay and its exploration from hills and lands causes serious geological problem and are exposed to landslide risk. Beside to this, burning or kiln firing of these conventional bricks allows huge amount of exhaust gases to the atmosphere leads to sever air pollution affects the ecological system of living hoods [8].

Furthermore due to excess amount of ingredients like lime, iron pyrites, alkalis, vegetation and organic matters into the bricks cause harmful actions such as melting and loses in shape, splitting of bricks, crystallization, disintegration, efflorescence and porosity etc., affects the quality of bricks [9]. These problems appear mainly during burning process. But in cement based building blocks, such harmful actions are rarely found.

To achieve a meaningful balance between natural resources and sustainable development, this research makes an effort to encourage the use of cement based building blocks parallel to conventional clay bricks. Nearly 80% volume of cement based building block is occupied by fillers, mainly the river sand. In same context this research also provides a healthy solution related to use of some alternative materials as filler instead of or with river sand. As per the review of literatures many researchers have used various varieties of fillers like fly ash class C and F [2, 6], gypsum, quarry dust or stone dust [2], brick waste [3], lower oxford clay (LOC) and ground granulated blast furnace slag (GGBS) [5]. To improve the mechanical properties of building blocks researchers have also used admixtures like mild steel fibre and water proof chemical [4].

II. ENVIRONMENT AND CONVENTIONAL BRICKS

In India the annual demand of building blocks is around 200 billion bricks and is rising day by day. Currently at least 1, 50,000 kilns are manufacturing more than 250 billion bricks per year in the country [7, 12]. The annual consumption of fertile soil is around 250 million tonnes and of coal is around 25 million tonnes annually shows the importance of conventional bricks [7]. Manufacturing of

cement also contributes towards air and noise pollution due to huge consumption of limestone. The problems related to environmental concern should immediately be addressed and these may be overcome by providing viable solution i.e., by reducing the use of naturally occurring materials.

It's really difficult to find relevant alternatives of clay bricks comprising rich construction qualities other than any brick. But the rising demand can be divided by producing and promoting cement based building blocks.

III. MATERIALS AND METHOD

Different category of raw materials used by various researches and their physical and chemical properties are discussed in this section.

A. Cement

Portland pozzolana cement (PPC), Portland cement (PC) and Portland composite cement CEM-II/AM (P-L) had been used by researchers in order to provide binding properties to bricks. Chemical compositions of cement used in various researches are shown in Table 1, whereas physical properties are showing in Table 2.

B. Fillers Materials

Types of filler materials utilized in various researches have been encountered in this research paper. The properties of such fillers are listed below.

a) Fly Ash: Fly ash (FA) is a powdered form of burnt coal captured from the chimneys of power plants. Production of FA during 2017-18 in India was around 196 MT and effective utilization was found to be 68% by various sectors and as result remaining portion was dumped out to lands [16]. Due to presence of pozzolanic properties, FA found to be effectively blended with the cement. ASTM broadly classifies FA into two classes named class F fly ash and class C fly ash. Class F fly ash produced due to hard burning of older anthracite and bituminous coal. It contains lime (CaO) with less than 10% which produce cementitious compounds when contact to water. While burning of younger lignite or sub bituminous coal is the reason of Class C fly ash production. It has self cemetitious properties due to presence of lime (CaO) with more than 20% [2]. The fineness modulus of FA lies in between 4.8 to 5.5 [10].

b) Gypsum: Due to valuable mechanical properties like low bulk density, higher sound absorbent, incombustibility, better fire resistance, negligible shrinkage, rapid drying and hardening, etc., gypsum may leads as a good construction material. Gypsum is a naturally occurring non- hydraulic binder form of soft crystalline rock or sand [2].

c) Quarry Dust: Quarry dust is a pollutant generated due to extraction activities of quarries. It is a solid waste in the form of dust that pollutes the environment. Around 175 million tonnes of quarry dust produced every year from quarries and about 250-400 million tonnes of quarry dust is generated at site. Due to presence of oxides of silica in higher amount, quarry dust may be a good alternative for naturally occurring siliceous material [2, 13].

d) Brick Waste or Debris: Brick waste or debris resulting from construction demolition and brick manufacturer may be found suitable to use in the form of filler material. The collected debris can be crushed into usable grain size by manually or using crusher. After gone through standard tests as applicable to filler material, debris can be reuse as per specification required. Chemical compositions of various types of fillers are showing in Table 3 and the physical properties of some filler materials are shown in Table 4.

Table 1. Chemical compositions of various cements [5, 15]

Types of cement	Compositions wt (%)								References
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O_3	K_2O	SO_3	
PC	20	6	3	63	4.21	-	-	2.3	[5]
CEM-II/AM (P-L)	21.77	6.38	2.68	56.66	2.33	1.25	1.06	1.32	[15]

Table 2. Physical properties of various cements [15, 3]

Type of cement	Properties					References
	Compressive strength	*Initial setting time*	*Final setting time*	*Standard consistency*	*Specific gravity*	
PC	53.0 MPa	30 min	10 hour	29%	3.15	[4]
CEM-II/AM (P-L)	46.43 MPa	194 min	306 min	-	3.05	[15, 3]

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Table 3. Chemical compositions of various types of fillers [12, 13, 15, 5, 14]

Types of Filler	Compositions wt (%)								References
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O_3	K_2O	SO_3	
Fly ash	48.3	13.7	6.2	3.9	1.9	1.0	2.1	1.7	[12]
Quarry waste	75.96	10.79	-	2.43	0.15	0.96	8.50	0.33	[13]
Debris	54.24	14.92	5.82	8.79	6.51	2.0	2.27	0.63	[15]
GGBS	35.35	11.59	0.35	41.99	8.04	-	-	0.23	[5]
Fly ash	41.8	17	5.3	5.9	1.6	0.2	0.6	0.7	[14]

Table 4. Properties of some types of materials used as filler in cement based building blocks [15]

Types of Filler	Properties					References
	Water absorption (%)	*Specific gravity*	*Rodded bulk density (kg/m^3)*	*Loose bulk density (kg/m^3)*	*Void content (%)*	
Sand	2.24	2.71	1741	1589	35.63	[15]
Debris	14.08	2.57	1210	1093	57.39	[15]

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Above chemical and physical properties of various wastes reveals that they can be used as natural filler like river sand and dirt in making cement based building blocks.

IV. Preparation of Cement Based Building Blocks and their Characteristics

Due to abundantly available pozzolanic materials such as fly ash, slag etc., and construction demolition wastes like brick debris, recycled fine and course aggregate, ceramic waste etc., their use in the form of raw materials are increasing as to preserve natural resources.

Begum et al. (2017) [2] reported on performance analysis of fly ash bricks and its comparison with common-red burnt clay bricks. Authors reported the use of fly ash in between 15 to 50%, lime 5 to 30%, gypsum 2%, and stone dust 23 to 53% to prepare several mixes for brick mould. Casted bricks were tested for water absorption, hardness, efflorescence, soundness, shape and size, crushing strength and basic compressive strength. Cement- sand mortar mix ratios of 1:3, 1:4 and 1:5 were used for analysis. Various types of mix proportions used into the research are shown in Table 5.

Table 5. Various mix proportions [2].

Proportion	Fly ash (%)	Lime (%)	Gypsum (%)	Stone dust (%)
P1	15	30	2	53
P2	20	25	2	53
P3	20	30	2	48
P4	25	20	2	53

Authors investigated that bricks made from proportion P3 i.e., at 20% fly ash, 30% lime, 2% gypsum and 48% stone dust, demonstrated better results as compare to other proportions. Authors concluded that fly ash bricks found more suitable as compare to burnt clay bricks and shows better mechanical parameters. Comparative analysis between red burnt clay bricks and fly ash bricks is shown in Table 6.

Table 6. Comparison between red burnt clay bricks and fly ash bricks [2].

Evaluated properties	Red burnt clay bricks	Fly ash bricks
Compressive strength	Around 35 kg/cm^2	Around 100 kg/cm^2
Porosity	More porous	Less porous
Weight	Heavier in weight	Lighter in weight
Thermal conductivity	1.25-1.35W/m2 ^oC	0.9-1.05 W/m2 ^oC
Water absorption	20-25%	6-12%

P5	30	15	2	53
P6	35	10	2	53
P7	40	5	2	53
P8	40	10	2	48
P9	50	25	2	23

Gadling and Varma (2016) [6] demonstrated the use of fly ash considering size of bricks as 22 X 10 X 7.5 cm. instead to fly ash, crushed sand also been used to prepare mix for brick moulds. Inspection and quality control was achieved by referring IS code considerations. Authors concluded that the average compressive strength of fly ash bricks was found 9.0 MPa much more than clay bricks 3.50 MPa. Water absorption, shape and size, density, weight, porosity, thermal conductivity of fly ash bricks was also found less than that of clay bricks which ensure that the fly ash bricks are more durable than clay bricks and hence fly ash bricks proven that it can be used as an alternative to clay bricks. "Fig. 1", shows the graph between compressive strength and sample number for fly ash bricks and normal clay bricks.

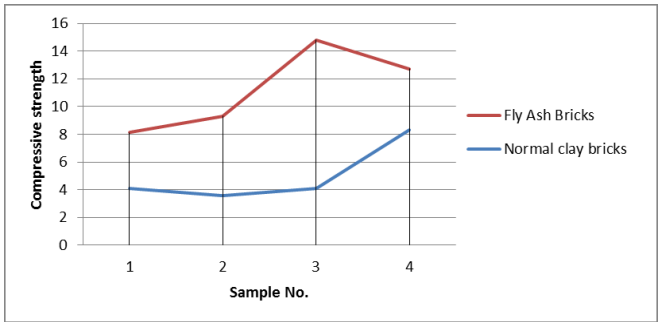

Fig. 1.Compressive strength [6]

Venkatesh et al. (2017) [10] reported on experimental investigation on cement brick with addition of quarry dust and fly ash. Three types of samples have prepared using different composition of materials. Mix proportions for various materials are shown in Table 7.

Table 7. Mix Proportion [10]

Sample	Cement%	Fly ash%	Quarry dust %	Total%
S_0	50	40	10	100
S_1	60	30	10	100
S_2	70	20	10	100

Authors concluded that proportion demonstrating sample S_2 shows better results for cement blocks in terms of compressive strength and water absorption and found relevant to normal bricks. Hence fly ash and quarry dust are found suitable and can be effectively replaced with natural resources. Comparative results between cement blocks and normal bricks are shown in Table 8.

Table 8. Comparative results between cement blocks and normal bricks [10]

Bricks/blocks type	*Avg. Compressive strength*	*Avg. Water absorption*
Normal Bricks	14.0 MPa	17%
Cement blocks from sample S2	13.5 MPa	13.2%

Ramkumar and Rubini (2017) [11] investigated on recycling of bricks (Re-Bricks). Materials used for investigations are brick debris and quarry dust, mixed at different proportions with cement. Quarry dust was used as base material to optimize the common mix, and debris were replaced with 5, 10, 15 and 20 % of quarry dust to attain the target strength. Authors concluded that at 20% replacement, Re- Bricks are found adequate in terms of strength and durability. The investigated parameters are shown in Table 9.

Table 9. Comparison between bricks [11]

Investigated parameter	Type of bricks	
	Re- Bricks with 20% debris	*Clay bricks*
Water absorption	20-25%	10-13%
Compressive strength	7.352 N/mm2	> 7 N/mm2
Shape and size	Uniform	Non uniform
Density	1600-1700 kg/m^3	1500-1700 kg/m^3
Fuel consumption	No	Yes
Pollution	No	High
Efflorescence	Slight	-

Sani and Muftah (2012) [1] reported on use of sand and waste paper sludge ash (S+WPSA) for manufacturing of bricks. The S+WPSA brick mixes were cast into 215 X 102.5 X 65 mm at normal consistency. Authors have concluded that a replacement of 60% WPSA with cement demonstrated better results in terms of durability and strength. Compressive strength of S+WPSA brick was conducted on three faces. The orientation of brick faces is shown in "Fig. 2". Highest compressive strength of 15.17 MPa was recorded by clay bricks as compare to S+SWPS bricks at 5.287 MPa and sand bricks at 1.76 MPa. Hence S+SWPS bricks fulfil all basic requirements and can be commercialized.

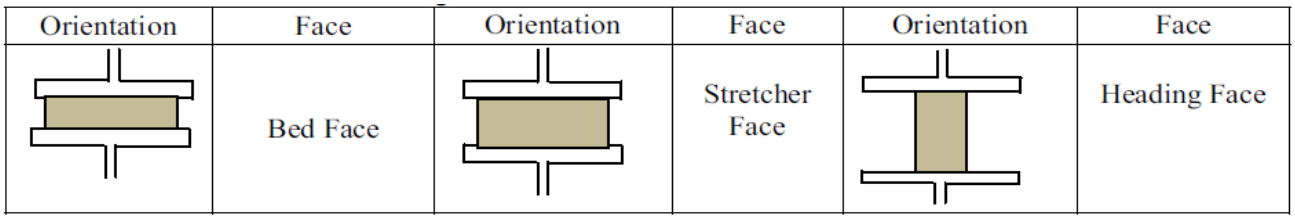

Fig. 2. Orientation of S+WPSA brick for compression test [1]

The above matter replicates that the cement based unfired building blocks can put great impact to the construction industries due to their superior engineering and construction qualities. The promotion and proper use of these building blocks can also lead towards sustainable and eco-friendly construction.

V. CONCLUSIONS

According to the review of previous researches following conclusions can be made,

1. Cement based building blocks are eco-friendly in nature, since there is no kiln firing required.
2. A huge save in natural resources may achieved by promoting fillers like fly ash, quarry dust, brick waste or debris, stone dust etc.,
3. Scarcity or landfill through dumping of non-biodegradable wastes and pollution caused due to their incineration can minimize by effective reutilization of such products in the form of construction materials.
4. Cement based building blocks are free from any fuel consumption.
5. No skill efforts required as the manufacturing process of cement based building blocks is simple and less timesaving.
6. Relevant durability and strength as required by a normal brick may achieved by cement based building blocks.

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