Review on Partially Replacement of Cement with Industrial Waste in Manufacturing of Concrete and Bricks

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1 Introduction

Cement is a commonly used building material that is essential for constructing durable and long-lasting structures. It is a fine powder made by heating a mixture of limestone, clay and other minerals in a kiln at high temperatures. Cement is primarily used as a binding agent in concrete, mortar, and stucco. Cement is the most important ingredient in the field of construction, starting from foundation to plastering of the buildings. Due to this, the production of cement reached up to 4.2 billion tonnes in the year 2020. This leads to increase in the release of greenhouse gases and environmental pollution; greenhouse gases such as nitrogen oxide causes various health problems, while sulphur dioxide is the major reason for acid rain and carbon monoxide can cause harmful health effects by reducing oxygen supply to the various organs and tissues. Reduction of the manufacturing and usage of cement will help in controlling the pollution on a large scale. While exploitation of river sand is also one of the major environment affecting act, an alternative material needs to be brought into use in the construction field. Blocks which have both cement and sand as the major parts of it, replaced of the material can help in reduce the environmental effect and cost of the manufacture of the blocks by 30–60%. Ground granulated blast furnace slag, a cementitious material that is a by-product of the iron-making blast furnaces, is mostly utilised in concrete. Blast furnace slag's primary constituents are CaO (30–50%), SiO_2 (28–38%), Al_2O_3 (8–24%), and MgO (1–18%). Up to respective values of 10–12% and 14%, the MgO and Al_2O_3 concentration exhibit the similar pattern, and after such values no further advancement is possible. The manufacturing of high slag blast furnace cement and Portland blast furnace cement both of which have GGBS contents that typically range from 30 to 70%, as well as the creation of ready mixed or site batched durable concrete, are two important uses

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of GGBS. It is commonly used as a pozzolan to make hydraulic cement or hydraulic plaster as well as to fully or partly replace Portland cement in the creation of concrete, with about 43% of it being recycled. Concrete and plaster are strengthened against moisture and chemical assault by pozzolans, which also ensure that the two materials set. When coal used in power plants is burned, a heterogeneous by-product called fly ash is created. It is a fine, glassy powder with a grey colour that rises with the exhaust gases. Fly ash contains pozzolanic elements, which when combined with lime, produce cementitious materials. The usage of fly ash is in concrete, mining, landfills, and dams [15, 17]. RHA is a by-product of the milling of rice. Its usage as a soil stabiliser is an environmentally advantageous substitute for final disposal. RHA is not naturally cementitious, cements must be created by adding a hydraulic binder, such as lime, to the RHA in order to reinforce the soil. An active pozzolana with numerous uses in the cement and concrete industries is rice husk ash. RHA is less expensive because it reduces the amount of cement required and lowers the total cost of making concrete. Reduced cement requirements lead to decreased cement plant pollution, which benefits the climate and the economy. They also provide a useful way to get rid of this farming waste product, which has few other applications.

2 Literature Review

A literature review is an evaluation report of information found in earlier literature which related to my project study. This chapter is explained briefly about the various literatures contained of the study of industrial waste materials and its physical and chemical properties.

Muleya et al. [8] made experimental study on RHA, which is used to make cement in small amounts, was used to test the integrity of concrete made in Zambia. The main objective was to evaluate the costs and benefits of using RHA in concrete. RHA was utilised in ratios of 10, 20, and 30% to replace cement in some places. The 20% cement replacement mix at a 0.5 water/binder ratio resulted in the optimal concrete strength 18 MPa. This resulted in a 12.5% decrease in the price of concrete, which is especially important for bigger concrete volumes.

Divahar et al. [3] made experimental examination on the compressive strength and physical characteristics of clay with GGBS brick is described in detail. Six various brick ratios, including 0, 5, 10, 15, 20, 25, and 30%, were examined. According to the findings, 5% of lime was continuously added to promote stability, and 5% of GGBS was increased and added in varied ratios. 20% of the entire amount of clay is now only used. The bricks are made using a straightforward manufacturing process that doesn’t include any additional equipment, plant, or machinery for autoclaving or fire. Consequently, compared to ordinary burnt clay bricks and calcium silicate bricks, the energy consumption will be significantly lower.

Vijaya et al. [13] evaluated that the potential effects of mineral admixtures on the compressive and flexural properties of cements including silica smoulder, fly ash, and rice husk ash. The current project uses concrete of M60 grade with a midway substitution made of fly debris, rice husk debris, and silica seethe (FA + RHA + SF = 30%) for three different proportions: 18:5:5, 18:6:6, 16:7:7. For M60 grade concrete, for blend construction, the actual water concrete percentage is 0.29 for a 50–75 mm droop. Increased pozzolanic action to stop concrete corrosion in coastal locations is an advantage of utilising FA, RHA, and SF.

Seevaratnam et al. [7] used earth cement blocks with RHA as a partial cement substitute are the subject of an experimental research in this work. RHA may only substitute 0–20% of the maximum binder in a cement block. For mechanical qualities, the investigations on earth cement blocks look at flexural tensile strength and compressive strength; for durability, they look at water absorption, sorption rate, and erosion against water spray. Up to 10% RHA content, a considerable improvement in the compressive and flexural tensile strength of earth cement blocks was noted due to the high SiO_2 content and strong reactivity of RHA. However, when the percentage of RHA replacement increases, the durability of earth cement blocks degrades, although only to a certain extent.

Phul et al. [11] describe about the compressive strength characteristics of concrete made with fly ash and GGBS in place of some of the cement. As a result of the use of waste materials as a cement substitute, the construction industry's greater demand for cement raises concerns about environmental deterioration. Using fly ash and GGBS. For various curing days, the optimal level of GGBS and fly ash was evaluated using different percentages ranging from 0 to 30%. When the compressive strength increased by 26.30% at 30% replacement compared to 0% control, and the slump value hit 30% compared to SF0, the workability of the substituted concrete improved. Results revealed that the addition increases the workability and compressive strength, which ultimately improves the mechanical properties of GGBS and fly ash.

Kumutha et al. [1] study involves the use of fly ash, GGBS, and manufactured sand (M-sand) to create bricks. Fly ash, GGBS, and cement are the main ingredients in the binder, which is used in a 1:2 mix ratio to create bricks. The test findings show that mix M1, which contains 75% fly ash, 15% GGBS, and 10% PPC, has a greater average compressive strength and minimum water absorption of 13.08%.

Manjunatha et al. [2] replaced a portion of the cement by GGBS up to 45%, this experiment aims to better understand the mechanical and fresh property strengths of concrete specimens, including compressive strength. Four different proportions of concrete mix-NC, Mix 1–15%, Mix 2–30%, and Mix 3–45% with and without GGBS were created. Our findings indicate that, for M35 and M40 grade concrete, a partial replacement of cement to GGBS up to 45% increased the degree of workability of the concrete.

Yogendra et al. [5] used concrete made with OPC and GGBS in various amounts ranging from 0 to 40% and looked at the compressive and flexural strength of the material. Compressive and flexural strength for 90 days of curing are only slightly reduced by 4% and 6%, respectively, when OPC is replaced by GGBS up to 20%.

Hossain et al. [10] included RHA with silicate, which is a component of pozzolanic materials. In an effort to substitute bricks and concrete, this RHA has been tried in place of cement. A standardised presentation of the experimental findings on bricks and concrete was made. The control specimen, or specimen without any RHA, was used as the basis for normalisation. Concrete loses both compressive and cracking tensile strengths when RHA is added. Additionally, it has been discovered that adding RHA to brick does not modify the shape or size of the brick, keeping the volume constant. However, adding RHA to brick reduces its crushing capabilities and increases its water absorption.

Oyetola et al. [9] validated the suitability of the constituent materials for constructing hollow sandcrete blocks made of OPC and RHA, preliminary examination of the materials was done. The freshly made blend was also put to a physical test. For 1, 3, 7, 14, 21, and 28 days, hollow sandcrete blocks of 150 mm by 450 mm were cast, cured, and crushed at replacement levels of 0, 10, 20, 30, 40, and 50%. According to test results, the majority of the commercial sandcrete blocks in Minna town are subpar. The OPC/RHA sandcrete blocks' compressive strength improves with age at curing and declines as the amount of RHA material rises. 20% was determined to be the ideal replacement amount by the study.

Summary of Literature Review

From the study of various literature review it is summarised as follows:

- Fly ash and GGBS can be replaced up to 30% with the cement, where its compressive strength will be increased.
- RHA can be used as a replacement of cement 10–20%. Using RHA, the water absorption will be increased.
- The amount of cement that is used in the cement block can be reduced up to 50% by adding fly ash, GGBS, and RHA at the correct ratio.

3 Material Properties

Cement—Cement is a fine powder that is widely used in the construction industry due to its excellent binding properties. Its physical properties, including fineness, colour, setting time, strength, density, heat of hydration, soundness, and consistency, affect its performance and suitability for various applications. The particle size of cement affects its workability and setting time, while its colour can vary due to the addition of pigments. The setting time of cement determines how quickly it hardens after being mixed with water, and its compressive strength is crucial for load-bearing structures. IS code refers to the Indian Standards code, which provides specifications and guidelines for the use of cement in construction in India. The Indian Standard code for cement is IS 269:2015, which provides specifications for different types of cement, including ordinary Portland cement, Portland pozzolana cement, rapid hardening Portland cement, and low heat Portland cement. The generalised physical properties of cement are provided in Table 1 by referencing to the journal papers.

Fly Ash—Fly ash is a fine, powdery material that is a by-product of burning pulverised coal in electric power generating plants. It is composed primarily of silica, alumina, and iron with small amounts of calcium, magnesium, and other

Table 1 Physical properties of cement

Physical properties	Cement	Fly ash	GGBS	RHA
Fineness	< 90 micron	10–100 micron	20–250 micron	5–15 micron
Bulk density (kg/m^3)	1440	800	1200	150
Colour	Grey	Dark grey	Off-white	Greyish black
Specific gravity	3.15	2.52	2.9	2.15

metals. Fly ash is classified as a pozzolanic material because it contains reactive silica and alumina compounds that react with calcium hydroxide in the presence of water to form cementitious compounds. When added to concrete, fly ash improves its strength, durability, and workability [12, 14]. It also reduces the amount of cement needed, which results in cost savings and a lower carbon footprint [16].

GGBS—GGBS is a pozzolanic material that reacts with calcium hydroxide in the presence of water to form cementitious compounds, similar to fly ash. GGBS is a sustainable material because it reduces the amount of waste generated by the steelmaking industry and reduces the carbon footprint of concrete production [4]. In addition, it has a lower embodied energy than Portland cement, which means that it requires less energy to produce.

Rice Husk Ask—Rice husk is a major agricultural waste product in many countries, and its disposal can create environmental problems. However, when burned at high temperatures, rice husk produces a fine, powdery ash that has a range of useful properties. RHA contains high levels of amorphous silica, which makes it a valuable material for use in various industries [6]. For example, it can be used as a partial replacement for cement in concrete to improve its strength, durability, and workability. RHA can also be used as a source of silica in the production of high-grade glass, ceramics, and refractory materials.

The chemical components of cement, GGBS, fly ash, and rice husk ash are given in Table 2.

4 Compressive Strength

Table 3 shows the compressive strength of GGBS, fly ash, and RHA with replacement for different proportions.

The values were obtained by varying the percentage of the GGBS in the concrete. From Fig. 1 it can be inferred that 20% replacement of GGBS attained high compressive strength.

The values were obtained by varying the percentage of the fly ash in the concrete. From Fig. 2 it can be inferred that 20% replacement of GGBS attained high compressive strength.

Table 2 Chemical components

Chemical component	Cement	GGBS	Fly ash	Rice husk ash
Calcium oxide (CaO)	64.97	40	3.58	0.87
Silica (SiO_2)	19.71	30.3	59.94	88.32
Ferric oxide (Fe_2O_3)	3.26	10.2	4.67	0.671
Alumina (Al_2O_3)	4.52	9.2	22.87	0.56
Sulphuric anhydride (SO_3)	2.44	1.5	0.35	
Magnesium oxide (MgO)	1.71	6.2	1.55	0.84
Sodium oxide (Na_2O)	0.42	0.8	0.62	0.12
Potassium oxide (K_2O)	0.54	0.4	2.19	2.91
(TiO_2)	0.13	0.8	0.94	–
(P_2O_5)	0.8	0.1	–	–
(MnO)	–	0.5	–	–
LOI	1.50	–	3.34	5.81

Table 3 Compressive Strength of GGBS

Replacement material	% Replacement	Day-7	Day-14	Day-28
GGBS	0	21.25	28.5	31.5
	10	28.15	30.3	31.5
	20	31.1	33.5	35.1
	30	23	26.32	28.4
Fly ash	0	19.5	23	26
	10	20	24.4	28
	20	22.6	28.2	33
	30	21	25.9	29
RHA	0	16.5	21	26
	5	17.3	22	27
	10	18	23.5	29
	15	15	22.5	27
	20	10.5	18	23

The values were obtained by varying the percentage of the RHA in the concrete. From Fig. 3 it can be inferred that 10% replacement of RHA attained high compressive strength.

The values were obtained by varying the percentage of the fly ash, GGBS, and RHA in the concrete. From the above graph it can be inferred that 20% replacement of GGBS, 25% replacement of fly ash and 15% replacement of RHA attained high compressive strength (Fig. 4).

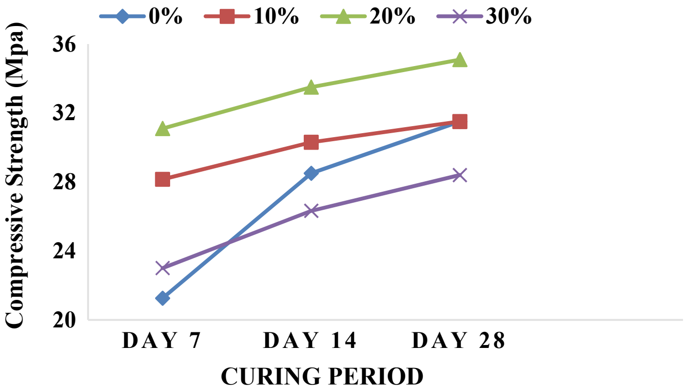


Fig. 1 Compressive strength for GGBS

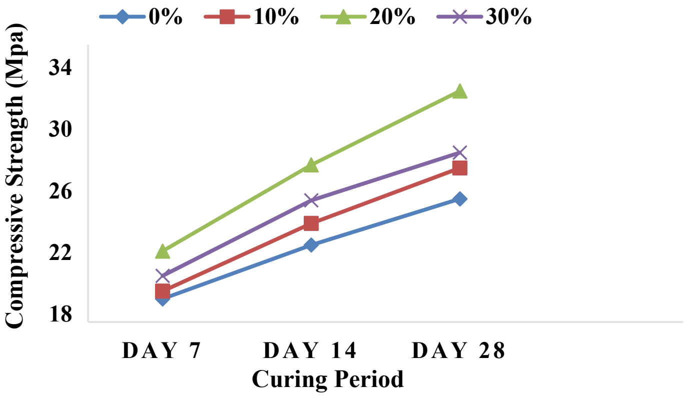


Fig. 2 Compressive strength for fly ash

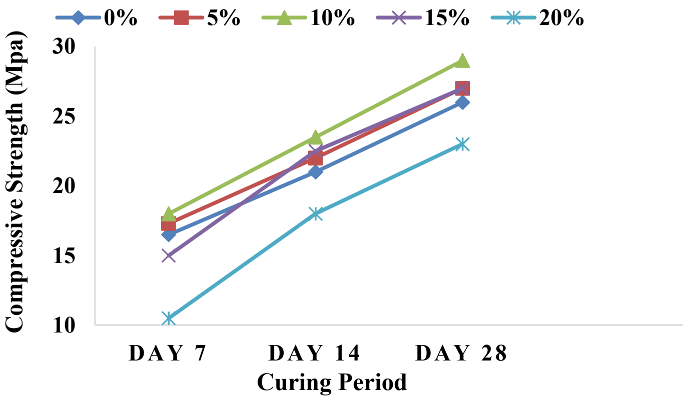
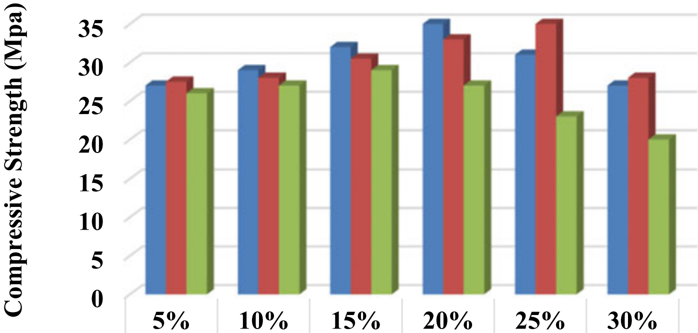


Fig. 3 Compressive strength for RHA



	5%	10%	15%	20%	25%	30%
GGBS	27	29	32	35	31	27
Fly ash	27.5	28	30.5	33	35	28
Rice husk ash	26	27	29	27	23	20

Replacementage Percentage

Fig. 4 Compressive strength comparison between fly ash, GGBS, and RHA

5 Conclusions

- The cost of GGBS is around 25–50% less than that of OPC, so replacing cement with it aids in lowering the cement content of concrete and lowering building costs.
- The current study demonstrates that using GGBS in place of traditional concrete can produce concrete with higher strengths. When 20% of the cement is replaced with GGBS.
- The earth cement blocks density was altered by the RHA replacement, rendering them lighter.
- The compressive and tensile strength of cement blocks significantly increased up to 10% RHA content due to the high SiO_2 content and strong reactivity of RHA.
- Fly ash and GGBS can be replaced up to 30% with the cement, where its compressive strength will be increased.
- RHA can be used as a replacement of cement 10–20%. Using RHA, the water absorption will be increased.
- The amount of cement is used in the cement block can be reduced up to 50% by adding fly ash, GGBS, and RHA at the correct ratio.

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