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Sustainable Unburned Bricks Made from Industrial Waste and Construction Demolition

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ABSTRACT

A few environmentally friendly substitutes for burnt clay bricks are FaL-G bricks, fly ash bricks, and geopolymer bricks. Fly ash, sand, and lime are the ingredients of an atypical fly ash brick. It has recently been discovered that powdered construction demolition waste (CDW) has strong pozzolanic properties and can be used as a substitute for cementitious materials like fly ash. WasteFoundrySand's (WFS) appropriate silica concentration, as determined by chemical analysis, making it a potential replacement for quarry dust and river sand, saving natural resources used in building. Waste marble powder (WMP) from marble rock quarries has a significant proportion of calcium oxide (CaO), which makes it a potential substitute for lime in the production of unburned bricks. Therefore, fly ash, powdered CDW, WFS, WMP, and lime are used in this study to create unburned bricks. The results of this study's Strength Activity Index (SAI) test showed that CDW and WFS lacked pozzolanic activity. To determine the ideal amount of CDW, WFS, and WMP in the production of unburned bricks, an experimental investigation was carried out. The results indicate that CDW can be added about 10–20%, WMP can be added up to 15% to replace lime, and WFS can be added up to 20% (i.e., it can fully replace river sand and M sand in the production of unburned bricks). The mixture of 60% FA, 15% WMP, 20% WFS, and 5% lime had a 9.13 MPa compressive strength. Strength of 7.29MPa was obtained by adding 10% of CDW as filler to the mix CD10FC50WM5. By using less cement, lime, and sand, the addition of WMP, CDW, and WFS will make the production of unburned bricks sustainable and environmentally benign.

Keywords: Construction demolition wastes (CDW); Waste Marble Powder (WMP); Waste Foundry Sand (WFS); Strength Activity Index (SAI).

1. Introduction

The construction business is expanding quickly both domestically and internationally. Massive growth in the building and industrial sectors has also resulted from rapid urbanization and industrialization (Jain, 2021). India's urban population is expected to grow from 377 million in 2011 to 600 million by 2031, and almost 70% of the buildings that are expected to be built in India by 2030 have not yet been built (Faruqi & Siddiqui, 2020). The amount of garbage produced in connection with these operations is likewise rising. According to estimates from the Centre for Science and Environment (CSE), India produced over 530 million tonnes of building and demolition waste in 2013 (building and Demolition Waste Factsheet, 2019).

Particularly in developing countries like India, the rapid growth of the residential and industrial sectors has increased demand for building materials, which has resulted in excessive use of natural resources and increased energy consumption. 750 million tonnes of sand, 242 million tonnes of lime stone, 2 billion tons of stone (aggregate), and 350 million cubic meters of soil were among the estimated annual building material consumption in India in 2018 (Ministry of Housing and Urban Affairs (MoHUA) and NITI Ministry, 2018). According to estimates, the total annual demand for sand in Karnataka was 26 MT in 2014; by 2030, that amount is expected to rise to 56–81 MT (Asundi, 2016). In order to reduce the use of natural resources in the brick-making process, CDW can be used in place of marl soil in the production of unburned bricks and stabilized earth blocks (Secon et al., 2018; Paula Junior et al., 2022). Because CDW possesses residual qualities, using it could lower the amount of cementitious material used to make unburned bricks (Duan et al., 2020).

One of the main sources of CO_2 emissions is the cement industry, which accounts for about 7% of India's total CO_2 output (International Energy Agency, 2018). Therefore, in order to address the problems of carbon dioxide emissions, the depletion of natural resources, and global warming, the construction industry must use novel construction approaches. (Poon and Jaillon, 2014). The use of CDW and industrial wastes in the production of building materials is one way to address these problems. In this work, trial specimens for unburned bricks were made using construction and industrial wastes such as CDW, Waste Foundry Sand (WFS), and Waste Marble Powder (WMP). After comparison with the strength standards specified in the code regulations, the viability of these specimens was determined and recommended for commercial use.

2. Materials and methods

Lime

For the experiment, lime from Class-C, which meets all requirements according to ASTM 141 and IS 712: 1984, was utilized. Class-C lime was utilized due of its accessibility in all regions of India.

Flyash

Flyash (FC) samples that met the requirements of Class-C of ASTMC618 were acquired from the Neyveli thermal power station. Lignite, the lowest grade coal with the least amount of carbon, was burned to produce flyash.

Construction demolition waste

From project sites close to Perungudi, Chennai, construction and demolition wastes (CDW) including concrete, brick masonry, and tile wastes were gathered and crushed to a fine size. The color of the ground CDW was grey.

Waste foundry sand

A byproduct of the foundry business, waste foundry exhaust sand (WFS) is created when green sand molds made of sand, bentonite, and charcoal are manufactured (Siddique & Singh, 2011). Table 1 lists CDW and WFS's physical characteristics.

Table1. Properties of WFS

Characters	CDW	WFS
Specificgravity	2.66	2.18
Finenessmodulus	3.66	3.66
Bulkdensity	1502(kg/m3)	1215(kg/m3)

Waste marble powder

Dolomite and limestone crystallize under high pressure and temperature conditions to make marble, a naturally occurring stone. Waste marble powder is produced when these marble stones are processed for a variety of uses. Table 2 is a list of WMP's physical characteristics.

Table2. Properties of WMP

Property	**Value**
$CaCO_3$	54%
$MgCO_3$	45%
Density	0.85gm/cc
Fineness	0% retention when sieved through 75µ sieve

MixProportion

The proportions in which the materials were blended are indicated in Table 4. WM and lime in place of gypsum and cement. As an extra filler, ground CDWistried was used, and WFS took the place of M-sand. The ratio of water to binder (Lime, WMP, and FC) was tested between 0.1 and 0.3. The mix reached the proper consistency at a water tobinder ratio (w/b) of 0.3. The components required to create the samples are shown in Figure 2.

A.)Lime B.)CDW C.)WFS D.)Flyash E.)WMP

Fig1.Ingredients for specimens

3. **Experimental methods**

Strength Activity Index (SAI)

SAI was carried out in accordance with ASTM C311's code standards. 450 grams of cement, 225 milliliters of water, and 1350 grams of sand were used to create the control specimen. The test samples had the identical material compositions, but CDW substituted 20% of the cement content in the first sample and WFS in the second. The SAI values are determined by calculating the samples' compressive strength at 7 and 28 days.

Compressive strength

The ingredients were first roughly combined, and water was added as needed to achieve the desired consistency. The resulting mixture is then put into three layers in a 70 x 70 x 70 mm mold, each of which is compressed 25 times. After 24 hours, the specimens were demolded and put in a hot air oven set to 60°C for 24 hours. Figure 2 displays a portion of the cast specimens. A As seen in Figure 2.b, the specimens were removed, allowed to cool to ambient temperature, and then evaluated for compressive strength.

Fig2.a) Cast samples b) Compressive strength testing of samples

4. Results and discussion

Strength activity index (SAI)

At 7 and 28 days, respectively, the control mix's compressive strength is 27.22 MPa and 31.47 MPa. Similarly, Table 3 displays the compressive strength findings of 20% cement substitution by CDW and WFS, which are 18.76 MPa, 22.42 MPa, 19.94 MPa, and 22.39 MPa at 7 and 28 days, respectively. The findings of three samples are averaged to determine the compressive strength values. The findings indicate that neither CDW nor WFS exhibit pozzolanic activity within the bounds of ASTM C618-22, 2022.

Table3.SAI values using CDW and WFS

SAI	7Days	28 Days
CDW	68.90%	71.24%
WFS	73.26%	71.14%

Compressive strength Test:

Table 4 lists the compressive strength values for each blend, and Fig. 3 shows the compressive strength of each mix. With 60% flyash, 20% WFS, 5% WMP, and 15% lime, MixFC60WM5 demonstrated a peak compressive strength of 9.13 MPa. The mix with the lowest compressive strength (0.283 MPa) was CD50WM15, which was composed of 50% CDW, 20% WFS, 15% WMP, and 15% lime.

Table4.Compressive strength of all mixes

Sl.No	MIXID	CDW	FC	WFS	WMP	Lime	28 days Compressive
		(%)	(%)	(%)	(%)	(%)	Strength (MPa)
1	FC60MS20		60	20(M-sand)		20	3.35
2	FC70MS20		70	20(M-sand)		10	5
3	FC60WS20		60	20		20	8.35
4	FC70WS20		70	20		10	6.59
5	FC60WM20		60	20	20		1.25

6	FC60WM15		60	20	15	5	5.57
7	FC60WM10		60	20	10	10	8.63
8	FC60WM5		60	20	5	15	9.13
9	FC50WM5		50	30	5	15	7
10	FC50WM10	10	50	20	10	10	5.7
11	CD10FC50WM5	10	50	20	5	15	7.29
12	FC40WM10	20	40	20	10	10	4.39
13	FC40WM5	20	40	20	5	15	5.19
14	FC30WM5	30	30	20	5	15	2.49
15	FC30WM10	30	30	20	10	10	5.88
16	CD40FC30WM10	40	30	10	10	10	4.38
17	FC50WS30WM10		50	30	10	10	3.4
18	CD50WM15	50		20	15	15	0.283
19	FC30WM15	30	30	10	15	15	1.96

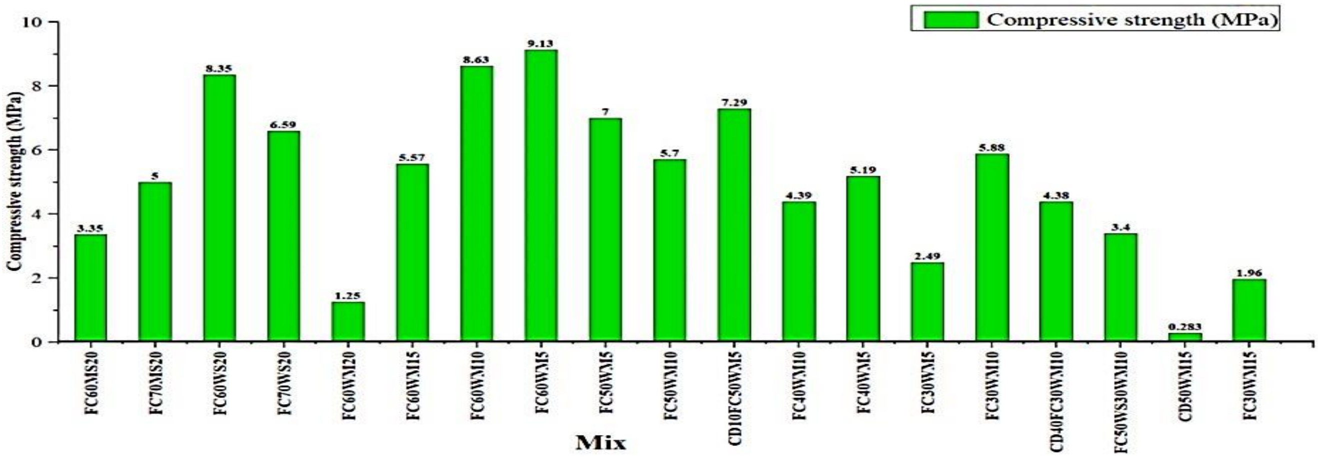

Fig3. Compressive strength of all mixes

The strength of specimens employing M sand and WFS as filler materials was compared using a mix combination of 60% FC, 20% M sand, and 20% Lime, according to the industrial flyash brick producer's report from Indore, India. When WFS was completely substituted for M-sand in mixes FC60WS20 and FC70WS20, the compressive strength increased by 149% and 31.8%, respectively, in comparison to FC60MS20 and FC70MS20. According to Sankarapandian et al. (2024), an increase in SiO_2 is linked to the strength gain of brick samples using WFS. For the duration of this investigation, Mix FC60WS20 is used as the control sample. These findings are shown in Figure 4.

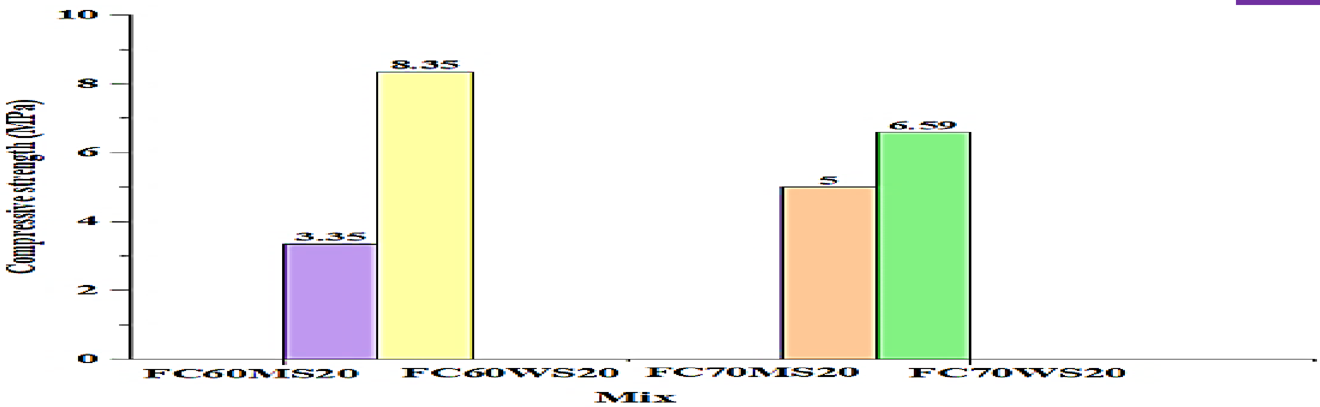

Fig4.Strength attainment comparison using M-sand and WFS

Effect of WMP substitution as binder

WMP can be used as a partial substitute for lime because it contains more than 50% CaO (Amin et al., 2020), which may increase the specimens' strength. As shown in Figure 5, substituting 5% and 10% of WMP for lime increased strength by 9.34% and 3.35%, respectively, in comparison to the control sample FC60WS20. The findings are consistent with the values that Andreani et al. (2024) suggested.

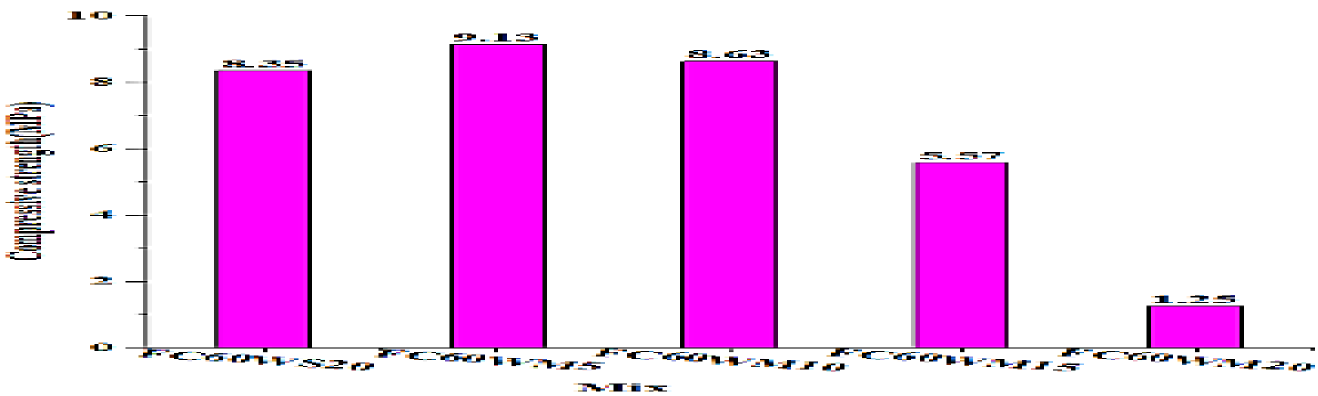

Fig5.Effect of WMP on the compressive strength of specimens

The results of adding CDW as a filler along with WMP and Lime combinations (Lime15% and WMP5%) and (Lime10% and WMP10%) are displayed in Tables 5, 6, and Figure 6a, b. For a 10% addition of CDW, the MixCD10FC50WM5 gavestrength was 7.29 MPa, and the results were compared to those of Soharu et al. (2022). Additionally, when ground CDW was applied, mullite and quartz peaks were seen, which were crucial for the bricks' strength characteristics.

Table5. Compressive strength for CDW addition for 5% lime and 15% WMP combinations

Sl.No	MIXID	CDW(%)	FC(%)	WFS(%)	WMP(%)	Lime(%)	28 days Compressive

							Strength(MPa)
1.	FC60WM5	-	60	20	5	15	9.13
2.	CD10FC50WM5	10	50	20	5	15	7.29
3.	FC40WM5	20	40	20	5	15	5.19
4.	FC30WM5	30	30	20	5	15	2.49

The FC60WM10 and FC30WM10 had a CDW replacement rate of 30% for FCgavestrength of 5.88 MPa. This could be because CDW uses less water than FC, which could lead to larger particles. Lime and WMP could be freely hydrated by excess water, helping to boost mix FC30WM10's strength when compared to FC50WM10 and FC40WM10.

Table6. Compressive strength for CDW addition for 10% lime and 10% WMP combinations

Sl.No	MIXID	CDW(%)	FC(%)	WFS(%)	WMP (%)	Lime(%)	28 days Compressive Strength(MPa)
1.	FC60WM10	-	60	20	10	10	8.63
2.	FC50WM10	10	50	20	10	10	5.7
3.	FC40WM10	20	40	20	10	10	4.39
4.	FC30WM10	30	30	20	10	10	5.88

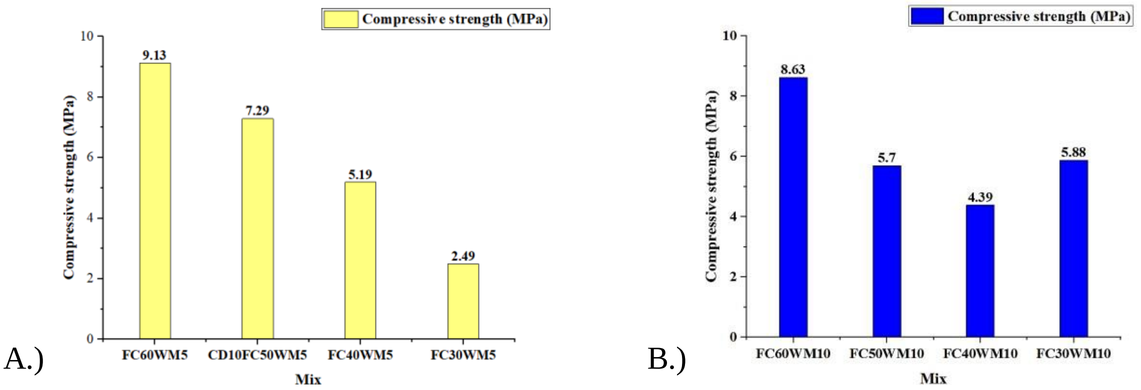

Fig 6. Effect of CDW replacement for a.)5%WMP b.)10%WMPaddition

Conclusion

The feasibility of using CDW and WFS instead of lime and produced sand in the production of flyash bricks was demonstrated by experimental study. There was a chance that WFS could take the place of produced sand. The ideal amount of WFS augmentation has been identified as 20%.

• The water-to-binder ratio can be set at 0.3; too much water increases the bricks' fluidity and degrades their strength.
• The ideal amount of lime and cement can be limited to 5% in order to achieve brick strength of up to 10 MPa. The head condition of WMP and CDW can achieve the remaining binding properties.
• According to IS 12894:2002, CDW could have been used as a binding material in the construction of unburned bricks of class-10 at a percentage of 10–20%.

6. **Future scope of work**

Strengthening eco-friendly bricks can be the focus of future research. To increase the structure's energy efficiency, an analysis of the eco-friendly bricks' durability and acoustic performance can be conducted. To analyze the usability of bricks in civil constructions, it is also necessary to examine the performance of eco-friendly bricks in masonry.

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