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Research Article

ASSESSMENT OF MECHANICAL AND DURABILITY PROPERTIES OF SUSTAINABLE COMPOSITE INTERLOCKING BRICKS FOR URBAN BUILDINGS

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Abstract

The mechanical and durability performance of composite interlocking bricks made with fly ash and manufactured sand (M-sand) as partial substitutes for traditional ingredients is examined in this study. Two brick sizes were assessed: 300 × 150 × 125 mm (B1) and 300 × 200 × 125 mm (B2). While durability qualities, such as initial rate of absorption (IRA) and sorptivity, were evaluated in compliance with ASTM C67 and compressive strength tests were carried out. Due to better particle packing and pozzolanic activity, the results show that replacing fly ash greatly boosts compressive strength up to an optimal level (F3), with increases of roughly 44% for B1 and 31% for B2 over the control mix. According to durability evaluation, IRA and sorptivity are significantly reduced by low to moderate fly ash substitution, suggesting improved pore structure and less capillary water absorption. Fly ash efficiently counteracts the negative effect of increased water absorption caused by greater M-sand levels.

Keywords: Composite brick, Interlocking brick, Flyash, Granite Waste Powder (GWP), Mechanical properties, Durability.

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1. INTRODUCTION

Due mostly to the widespread use of traditional clay and concrete bricks, the construction sector is one of the biggest users of natural resources and a significant cause of environmental contamination. There is a need for sustainable and environmentally friendly alternatives because the production of typical masonry units uses a lot of energy and produces large carbon emissions. Large-scale production of solid and industrial wastes, such as crumb rubber from tires that are nearing the end of their useful lives and granite waste powder from stone processing, presents problems for the environment. In addition to addressing environmental issues, using these waste materials in construction offers the possibility of improving material qualities including decreased density, increased ductility, and improved energy absorption. The successfully built machine setup was used to create interlocking flyash bricks. Most of the arrangement

consists of the machine frame, hydraulic system, and pan mixer. Two varieties of interlocking bricks were produced: 12" x 6" x 5" and 12" x 8" x 5". According to the test results, interlocking bricks are preferable to ordinary bricks [1]. With a maximum compressive strength of 12.35 MPa with 8 M NaOH, a Na₂SiO₃/NaOH ratio of 2, and an alkaline solution-to-binder ratio of 0.3, geopolymer bricks with 40% MI ash (MIA B9) outperformed IS 3495 requirements. With 40.7–42.8% less weight gain in sodium sulphate, sodium chloride, and seawater and 23.3–42.8% lower IRA values than traditional clay and fly ash bricks, they also demonstrated enhanced durability and chemical resistance, underscoring their potential as high-performance, sustainable building materials [2]. Superior performance was demonstrated by concrete pavement bricks containing 5% CFA + 10% MSWIBA and 10% CFA + 20% MSWIBA, with BA20FA10

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attaining the greatest 28-day compressive and flexural strengths of 52.8 MPa and 6.2 MPa, respectively. There were three stages to the water absorption: steady state, slower descent, and rapid drop. Along with minimal heavy metal leaching, the bricks also showed outstanding freeze-thaw and sulfate resistance [3]. Higher replacement levels decreased workability and strength, however replacing 20% of fine aggregates with CBP and 30% of coarse aggregates with RCA produced the best strength, with 28-day compressive and tensile values rising by 8.24% and 2.89%, respectively [4]. Mortars with a yield stress of 13.8 Pa, a viscosity of 11.7 Pa·s, and a 25% BW replacement attained a flow time of 64.1–74.2 s and 28-day flexural and compressive strengths of 4.03 MPa and 36.9 MPa, respectively—11.3% and 39.2% less than the norm. Sulfate resistance dropped by 39% in comparison to BW0%, whereas water absorption and chloride penetration rose by 86.2% and 36%, respectively [5]. The 70% waste geo-cement mortar mixture acquired a flexural strength of 12 MPa, whereas the 7-day 50% waste brick mixture attained a compressive strength of 61 MPa. For large load-bearing applications, all combinations had compressive strengths more than 40 MPa. 100% waste brick AAMs exhibited the least loss under acid and chloride attacks, whereas 50% waste geo-cement mortar had the lowest water absorption (6%) and minimum freeze-thaw strength loss. The mortar made with 50% waste brick aggregate performed the best overall [6]. The mechanical, thermal, and durability characteristics of adobes have been found to have improved globally. Additionally, neem fibers from leaves have a significant impact on thermal comfort, but their use has a detrimental effect on durability. Adobes reinforced with neem fibers, however, are appropriate as building materials with significant environmental and thermal comfort advantages [7]. At the same density, clay, shale, and refractory bricks only achieved 40–66% of the compressive strength of concrete bricks, although concrete facing bricks demonstrated higher mechanical qualities and durability. Leca concrete facing bricks with a density of at least 1700 kg/m³ satisfied the standards for water absorption and standard compressive strength [8]. For the identical cement proportions of 6% and 12%, compositions made with CW had greater mean outcomes than those made with potable water. At 49 days, CSEB with CW and 12% cement had the lowest water absorption (12.91%) and the maximum compressive strength (4.9 MPa). After six wetting-drying cycles, it also displayed the least amount of mass loss (0.3%) [9]. All samples mechanical and physical characteristics were similar to those of conventional bricks, demonstrating that the addition of trachyte already gives enough technical features at 900°C, enabling additional manufacturing cost reduction by lowering firing temperatures [10]. Lastly, when the fire temperature rose, particularly at 1100 °C, the bricks' resistance to salt crystallization improved. While bricks burnt with fine eggshells showed almost similar values, bricks without residues were the most durable at this temperature. Although there was more variation in the outcomes at lower

firing temperatures, bricks containing eggshell generally appear to be more resilient than those without [11]. The findings show that as WD cycles increase, there is a notable decrease in the UCS, BTS, and PLI. Visual inspection revealed that the growth of microcracks in the bricks during WD cycles was the cause of the loss in the UCS, BTS, and PLI. The clay mineral concentration and porosity of the bricks had a significant impact on the rates of loss (RL) of UCS, BTS, and PLI during the WD process [12]. Because of variations in the microstructure of the ash, the bricks showed different water interactions. It was discovered that a high periclase (MgO) content improved their durability and mechanical qualities [13]. Compared to clay bricks, which had a compressive strength of 10–20MPa, bricks with a 40% char content demonstrated a high compressive strength of 49.2–52.5 MPa. At 28 days, GO's strength somewhat reduced while AE's strength slightly increased. With boiling water absorption $\leq 2.3\%$ (90% less than untreated) and 120 freeze-thaw cycles compared to 22 for untreated bricks, treated char bricks showed significantly increased durability [14]. Bricks with higher EPS and WRTP doses were lighter and more thermally efficient. Bricks with 0.5% EPS and 0.5% EPS + 5% WRTP met minimum compressive strength and weathering resistance, demonstrating their potential for high-performance, sustainable polymer waste bricks [15]. While mercury intrusion porosimetry found fewer big pores and a single pore family in EICP-stabilized samples, triaxial testing revealed more cohesiveness in treated materials. Higher calcium carbonate content and water-repellent coatings could enhance properties even more [16]. In comparison to air-cured mixes, 1.5% PEG 6000 boosted the 28-day compressive strength of self-curing concrete by 48.9%, 2% PEG enhanced durability by lowering water absorption, sorptivity, and shrinkage by 37.5%, 27%, and 44%, and 4% PEG reduced chloride penetration by 78.7%. Compressive, splitting tensile, flexural, and modulus of elasticity strengths increased by 55.6%, 55.35%, 54.47%, and 28%, respectively, when 50% CC was replaced with 1% PEG [17]. Although the addition of SCMs increases strength, it may also increase brittleness; this can be countered by adding fibers. Additionally, the addition of SCMs has a significant impact on workability and frequently has a detrimental effect on decreasing it [18]. The mechanical behavior, shrinkage, durability, and fresh-state characteristics of SCM were assessed. The 28-day compressive strength was marginally lowered by 3.3% and 16.9%, respectively, when 25% and 50% RBS were substituted for limestone sand, while still meeting EN 998-2 brick mortar requirements [19]. The most recent research on the mechanical qualities, durability, 3D printing uses, structural performance, and sustainability aspects of CDW-based geopolymers is summarized in this review, which emphasizes important elements like the impact of CDW precursors and aggregates, mix design parameters, particle packing, and shape characteristics [20]. Because of its porous, honeycombed structure, adding BKRHA decreased the workability of the GEOPAV mix while having

minimal impact on compressive strength. Nonetheless, resilience against acid and frost attacks was much increased, and split tensile and flexural strengths improved [21]. Although less effective against freeze-thaw and chloride penetration, concrete containing 25% CGCA, 20% CGFA, and 2.5% CGMA attained C30 strength (30.8 MPa) and enhanced sulfate resistance. While untreated CG reduced carbon emissions by around 8%, the mix improved hydration and decreased porosity, providing information for mine backfill applications and sustainable building [22]. Based on this idea, epoxy resin and polyethylene were used to create an EP-PE superhydrophobic coating with excellent mechanical qualities and potent antifouling and anticorrosion properties. More significantly, the sustainable superhydrophobic coating can preserve the microstructure's integrity in a manner akin to that of living things, so achieving the surface microstructure's durability [23]. Research on water absorption showed that adding 5% BCBP to concrete improved its water absorption capabilities when compared to control concrete. Concrete mixes with 5% BCBP had the best behavior for both exposures, according to the results of durability testing. Additionally, the application of BCBP in rubberized concrete appeared to have prevented significant losses in mass, strength, and diameter [24]. Asphalt mixes containing 25–100% CC in place of HL were assessed. In order to evaluate mechanical qualities and durability, fillers were physically and chemically evaluated, and mixes were tested for bulk density, air voids, TSR, and wheel tracking [25]. The mixtures with the lowest alkali activator level, 0.86% and 0.37%, exhibited a compressive strength of 17 MPa and a density of 1.2 g/cm³. The developed alkali-activated concrete's potential to sequester carbon dioxide was enhanced to 180 kgCO_{2eq}/m³ by lowering the alkali-activator percentage [26]. The present study takes into account of two distinct brick sizes, the current study methodically examines the mechanical and durability performance of composite interlocking bricks that contain fly ash and produced sand. In order to create an interlocking masonry system that is optimal, sustainable, and structurally sound, the research focuses on compressive strength, initial rate of absorption, and sorptivity in addition to durable behavior.

2. EXPERIMENTAL WORK

For dimensions B1 (300 × 150 × 125 mm) and B2 (300 × 200 × 125 mm), the mechanical characteristics of composite interlocking bricks, including compressive strength, were evaluated. A 300-tonne Compression Testing Machine (CTM) was used to test the bricks [27-29]. The experimental setup for determining the brick specimen's compressive strength is shown in Figure 1. Until the sample failed, a constant axial pressure of 14 N/mm²/minute was applied.



Figure 1: Compressive strength testing setup

The durability of composite interlocking bricks was assessed by measuring initial absorption and sorptivity. According to ASTM C67, the Initial Rate of Water Absorption (IRA) gauges unidirectional water uptake at intervals of one and two minutes. The total 102 composite interlocking bricks both B1 and B2 were coated with Nitocote SN522. Table 1 shows the different combination of the interlocking bricks. The numerical numbers 5,10,15,20,25,30,40,50,60 in the table represents the material replacement weight percentage. Bricks were placed in a tray filled with three millimeters of water, and their weights were noted both before and after they were submerged for one and two minutes. Figure 2 illustrates the visual representation of the IRA test.

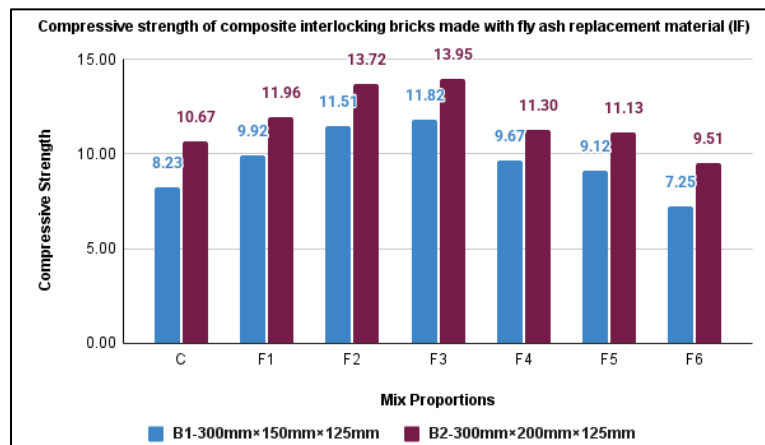


Figure 2: Test set up for Initial Rate of Absorption

Table 1: Proportions for the mixture of composite interlocking bricks

S. No	Mix			Various Ingredients in Percentage					
	Type	Composition	ID	F	GWP ¹	L ^s	G [*]	MS	CR [^]
Interlocking brick mix without waste materials									
1.	CON	Control	C	60	-	12	3	25	-
Interlocking bricks made with fly ash replacement materials (IF)									
2.	F	GWP10	F1	50	10	12	3	25	-
3.		GWP20	F2	40	20	12	3	25	-
4.		GWP30	F3	30	30	12	3	25	-
5.		GWP40	F4	20	40	12	3	25	-
6.		GWP50	F5	10	50	12	3	25	-
7.		GWP60	F6	-	60	12	3	25	-
Interlocking bricks with M sand replacement materials (IMS)									
8.	MS	CR5	M1	60	-	12	3	20	5
9.		CR10	M2	60	-	12	3	15	10
10.		CR15	M3	60	-	12	3	10	15
11.		CR20	M4	60	-	12	3	5	20
12.		CR25	M5	60	-	12	3	-	25
Interlocking bricks made with F and MS replacement materials (IFMS)									
13.	F [#] +MS [@]	GWP10+CR5	FM1	50	10	12	3	20	5
14.		GWP20+CR10	FM2	40	20	12	3	15	10
15.		GWP30+CR15	FM3	30	30	12	3	10	15
16.		GWP40+CR20	FM4	20	40	12	3	5	20
17.		GWP50+CR25	FM5	10	50	12	3	-	25

F[#] - Fly ash, MS[@] - M Sand, L^s - Lime, G^{*} - Gypsum, GWP¹ - Granite Waste Powder, CR[^] - Crumb Rubber

**Figure 3:** Compressive strength of IF

A material's capillary water absorption is measured by its sorptivity. The test measures the mass of composite interlocking bricks at regular intervals until full saturation, in accordance with ASTM C67. To examine water intake, absorption is plotted against the square root of time.

3. RESULTS AND DISCUSSION

Fly ash and lime content, gypsum, particle size, and pore volume in M sand are some of the variables that affect a brick's compressive strength. As a binder, lime improves hydration and increases strength. Strength growth is also aided by Class F fly ash, which has low calcium oxide level (<10%) and pozzolanic qualities.

For two brick sizes, B1 and B2, Figure 3 shows the compressive strength of composite interlocking bricks that incorporate fly ash replacement material (IF) across various mix proportions (C, F1–F6). When fly ash is added to both brick configurations, the compressive strength first rises and reaches its maximum at mix F3. At greater replacement levels, the strength of the brick falls. Compressive strengths of 8.23 MPa and 10.67 MPa for B1 and B2, respectively, were noted for the control mix (C). The filler effect and pozzolanic activity of fly ash, enhances the particle packing and aids the development of more calcium silicate hydrate gel, resulting in a denser microstructure, are responsible for the strength augmentation up to F3. At F3, the highest compressive strength values of 11.82 MPa for B1 and 13.95

MPa for B2 indicate increases of roughly 44% and 31%, respectively, over the control mix. For both brick sizes, a progressive decline in compressive strength is observed beyond the ideal replacement level (F3). The excessive fly ash content at mixes F4 to F6 may be the cause of this drop, which lowers the bricks' load-bearing ability by increasing porosity and causing insufficient calcium hydroxide for efficient pozzolanic reactions.

Because of their greater cross-sectional area and better stress distribution, bricks of size B2 generally show higher compressive strength than B1 for all mix amounts. The findings show that the mechanical performance of composite interlocking bricks is improved at an ideal fly ash replacement level (about mix F3), which qualifies them for sustainable masonry applications without sacrificing structural integrity.

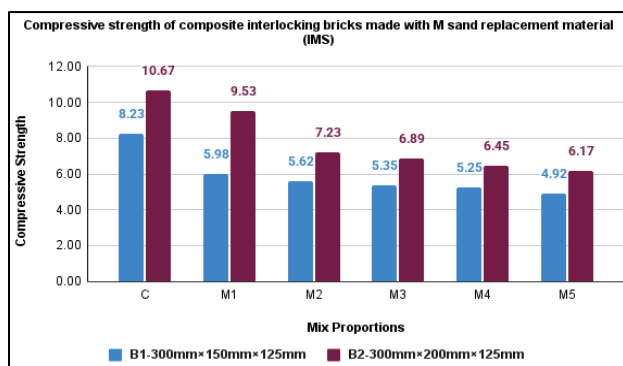


Figure 4: Compressive strength of IMS

For two brick sizes, B1 and B2, the compressive strength of composite interlocking bricks made with M-sand replacement material (IMS) is shown in Figure 4 for mixes M1 through M5 and the control mix (C). As the amount of M-sand replacement increases, a discernible decline in compressive strength is shown for both brick sizes. The highest compressive strength is shown by the control mix, which has values of 8.23 MPa for B1 and 10.67 MPa for B2. The compressive strength significantly decreases when M-sand is partially substituted, especially at M1, suggesting that M-sand has an instant impact on the interlocking bricks' mechanical performance. The compressive strength drops to 4.92 MPa for B1 and 6.17 MPa for B2 at the maximum replacement level (M5), which is a fall of almost 40% and 42%, respectively, from the control mix. The angular particle shape, higher fines content, and surface texture of M-sand, which can negatively impact workability, compaction efficiency, and the quality of the interfacial transition zone between aggregate particles and the cementitious matrix, the strength decrease with increasing M-sand content. These elements could result in more micro-voids and poorer bonding, which would lower the bricks' ability to support loads.

For two brick sizes, B1 and B2, the compressive strength of composite interlocking bricks made with integrated fly ash

and M-sand replacement materials (IFMS) is shown in Figure 5 for the control mix (C) and mixes FM1 to FM5. All IFMS mixtures show a loss in compressive strength when compared to the control mix, but the decrease is more gradual and moderate than in mixes that just contain M-sand. Compressive strengths of 8.23 MPa for B1 and 10.67 MPa for B2 are achieved by the control mix. When fly ash and M-sand are added together, the strength drops to 8.06–6.12 MPa for B1 and 9.19–8.14 MPa for B2 spanning FM1–FM5. For B1, the lowest strength is recorded at FM3 (6.12 MPa), however a slight strength recovery is seen at higher replacement levels (FM4 and FM5), suggesting that fly ash has a somewhat compensatory impact.

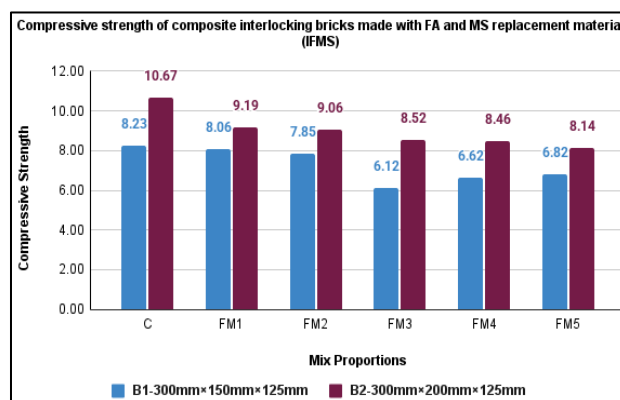


Figure 5: Compressive strength of IFMS

3.1. DURABILITY PROPERTIES OF COMPOSITE INTERLOCKING BRICKS

The rates at which bricks absorb water at first contact are measured by the Initial Rate of Absorption (IRA). High suction bricks have a high suction rate, whereas low suction bricks have a low rate.

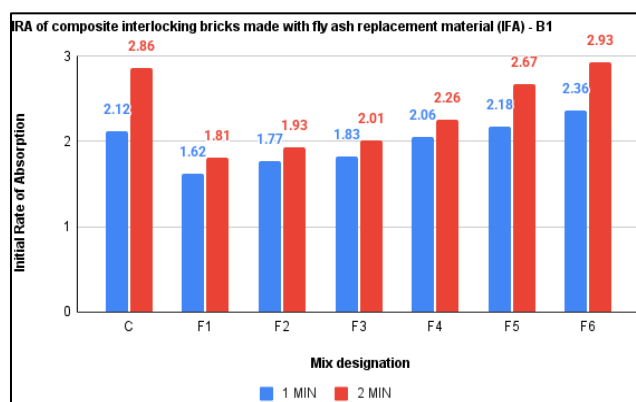


Figure 6: Initial rate of absorption of IFA – B1

The initial rate of absorption (IRA), evaluated at 1- and 2-minute intervals, for composite interlocking brick (B1) using fly ash as a replacement material (IFA) for different mix designations (C, F1–F6) is shown in Figure 6. With an increase in fly ash concentration, the IRA values exhibit a clear pattern that reflects modifications to the bricks' surface properties and pore structure. At one minute and two minutes,

respectively, the control mix shows comparatively higher IRA values of 2.12% and 2.86%. When fly ash is added, there is a noticeable decrease in IRA up to mix F1, where the lowest values of 1.62% (1 min) and 1.81% (2 min) are noted. Fly ash's filler effect, which improves surface densification, decreases capillary continuity, and refines pore structure in the early phases of absorption, is responsible for this decrease. Mixtures F2 through F6 show a steady rise in IRA after F1. An increase in unreacted fly ash particles and delayed pozzolanic activity may be linked to the rise in absorption at higher fly ash replacement levels. This would result in a relatively larger volume of fine pores and greater water infiltration during the initial absorption period. However, the IRA values are still on par with or somewhat greater than those of the control mix, even at higher replacement levels. For all mix proportions, IRA values at 2 min are consistently higher than those at 1 min, indicating progressive water uptake with time. Overall, the results suggest that a low to moderate level of fly ash replacement effectively reduces the initial rate of absorption of B1 interlocking bricks, contributing to improved durability performance, while excessive replacement may partially offset this benefit due to increased pore connectivity.

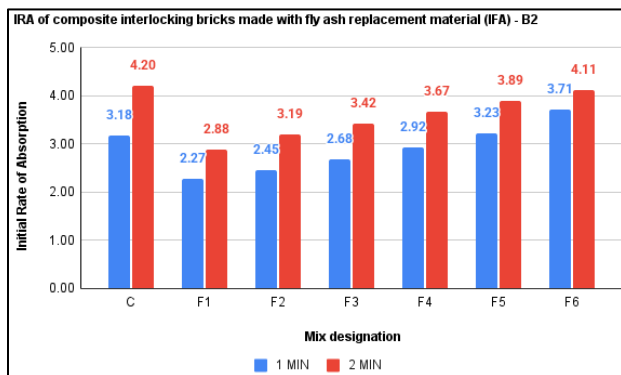


Figure 7: Initial rate of absorption of IFA – B2

The initial rate of absorption (IRA) of composite interlocking bricks of size B2 (300 × 200 × 125 mm) using fly ash as a replacement material (IFA) is shown in Figure 7 and is measured at 1 and 2 minutes for mixes F1 through F6 and the control mix (C). The findings show that the addition of fly ash has a major impact on the bricks' early-age water absorption properties.

The greatest IRA values are seen in the control mix, which measures 3.18% at 1 minute and 4.20% at 2 minutes. A significant decrease in IRA is seen at mix F1 after partial replacement with fly ash; the lowest values of 2.27% (1 min) and 2.88% (2 min) are noted there. Fly ash's micro-filler effect, which enhances particle packing and decreases surface-connected capillary holes, is mostly responsible for this decrease in initial water infiltration.

A steady rise in IRA is noticeable at both exposure durations as the fly ash content increases from F2 to F6. This pattern implies that the existence of finer, partially linked

pores that enable more initial absorption occurs when the supply of calcium hydroxide becomes insufficient for a full pozzolanic reaction at higher replacement levels. The IRA values, however, are still on par with or marginally below those of the control mix even at the maximum replacement level (F6). Time-dependent absorption behaviour is confirmed by the fact that the IRA measured at 2 minutes is consistently higher than that at 1 minute for all mix proportions. B2 bricks have higher absolute IRA values than B1 bricks, which may be related to their bigger exposed surface area and geometrical arrangement. All things considered, the results show that a reasonable amount of fly ash replacement successfully lowers the initial rate of absorption in B2 interlocking bricks, improving durability performance.

The IRA test findings for M sand replacement materials (IMS) are illustrated in Figures 8 and 9.

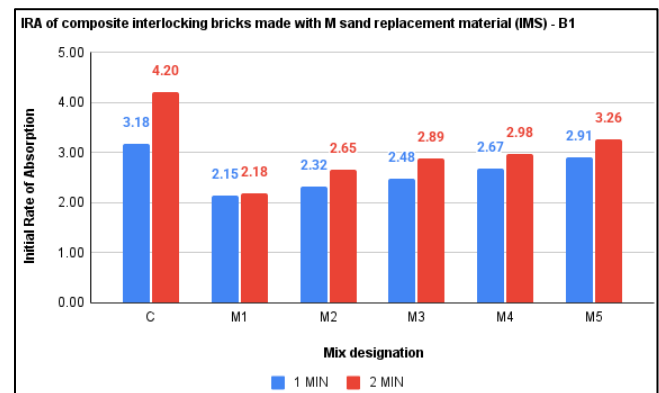


Figure 8: Initial rate of absorption of IMS – B1

The initial rate of absorption (IRA) of B1 composite interlocking bricks made with M-sand replacement material (IMS) is shown in Figure 8 at 1 and 2 minutes for mixes M1 through M5 and the control mix (C). The findings clearly show that replacing M-sand has a major impact on the bricks' early-age water absorption properties. The IRA values of 3.18% at 1 minute and 4.20% at 2 minutes are comparatively high for the control mix. A significant decrease in IRA is seen at mix M1, where the lowest values of 2.15% (1 min) and 2.18% (2 min) are noted, when natural sand is partially replaced by M-sand.

Improved particle interlocking and better M-sand gradation at lower replacement levels may be responsible for this initial decrease in surface capillary porosity. However, the IRA values progressively rise at both measurement intervals when the M-sand content increases from M2 to M5, reaching 2.91% (1 min) and 3.26% (2 min) at M5. IRA values at 2 minutes are consistently greater than those at 1 minute for all mix proportions, suggesting increasing absorption over time.

Composite interlocking bricks of size B2 with M-sand replacement material (IMS) have their initial rate of absorption (IRA) measured at 1 and 2 minutes for the control

mix (C) and mixes M1 through M5. This is shown in Figure 9. The findings show that the M-sand content clearly affects the bricks' early water absorption behaviour. IRA values for the control mix are 3.18% at one minute and 4.20% at two minutes. The addition of M-sand results in a minor improvement in surface densification at low replacement levels, as seen by the minimal decrease in IRA at mix M1, especially at the 1 min interval (3.10%). However, additional increases in the M-sand content do not maintain this reduction. IRA values gradually rise from M2 to M5 at both measurement intervals, peaking at M5 at 3.97% (1 min) and 4.31% (2 min).

The initial rate of absorption (IRA) of composite interlocking bricks of size B1 containing combined fly ash

and M-sand replacement materials (IFMS) is shown in Figure 10 at 1 and 2 minutes for the control mix (C) and mixes FM1 to FM5. The results show that, especially at lower replacement levels, the introduction of the combined replacement materials significantly reduced IRA.

The IRA values of 3.18% at 1 minute and 4.20% at 2 minutes are comparatively high for the control mix. A significant drop in IRA is seen at mix FM1, where the lowest values of 1.32% (1 min) and 1.87% (2 min) are noted upon the addition of fly ash and M-sand. A steady increase in IRA is observed at both measurement intervals when the replacement level rises from FM2 to FM5, reaching 2.07% (1 min) and 2.69% (2 min) at FM5.

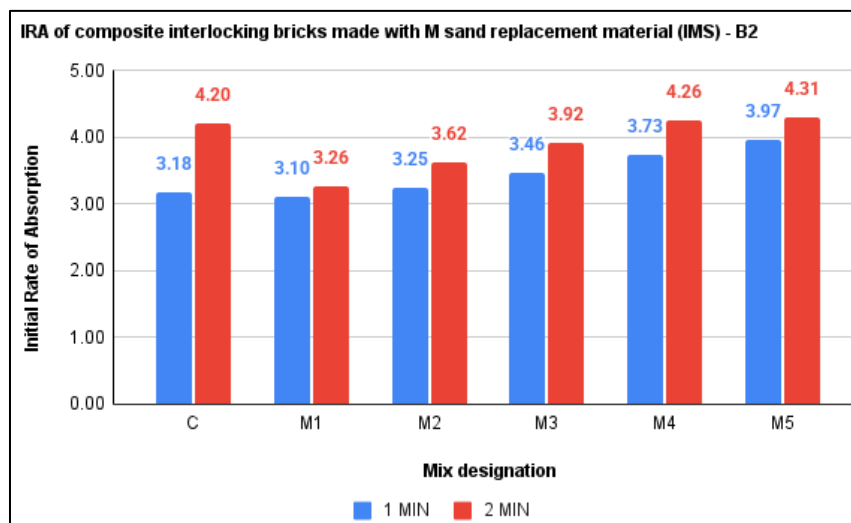


Figure 9: Initial rate of absorption of IMS – B2

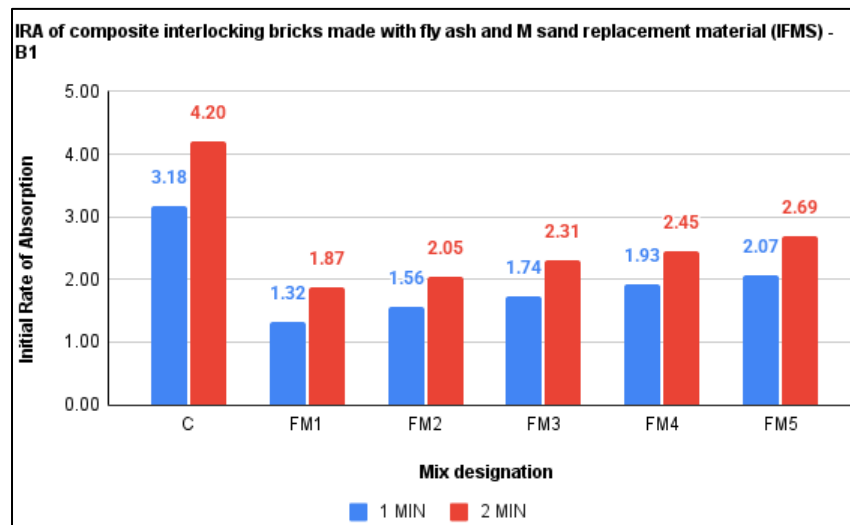


Figure 10: Initial rate of absorption of IFMS

Using composite interlocking bricks of size B2 with combined fly ash and M-sand replacement materials (IFMS), Figure 11 shows the initial rate of absorption (IRA) at 1 and

2 minutes for the control mix (C) and mixes FM1 to FM5. The findings demonstrate the positive impact of the combined replacement materials on the bricks' early-age water absorption performance. The highest IRA values, 3.18% at 1 minute and 4.20% at 2 minutes, are recorded by the control mix. The lowest values of 2.13% (1 min) and 2.62% (2 min) are obtained at mix FM1, where a considerable decrease in IRA is shown with the introduction of IFMS.

The IRA values gradually rise at both measurement intervals as the replacement level rises from FM2 to FM5, reaching 3.07% (1 min) and 3.98% (2 min) at FM5. The

results show that replacing fly ash and M-sand together can effectively lower the initial rate of absorption of B2 interlocking bricks. The best durability performance is provided by lower to moderate replacement levels (FM1–FM3).

3.2. SORPTIVITY

Sorptivity quantifies the surface absorption properties of bricks. The inherent vulnerability of masonry components mostly arises from insufficient adhesion and bond strength.

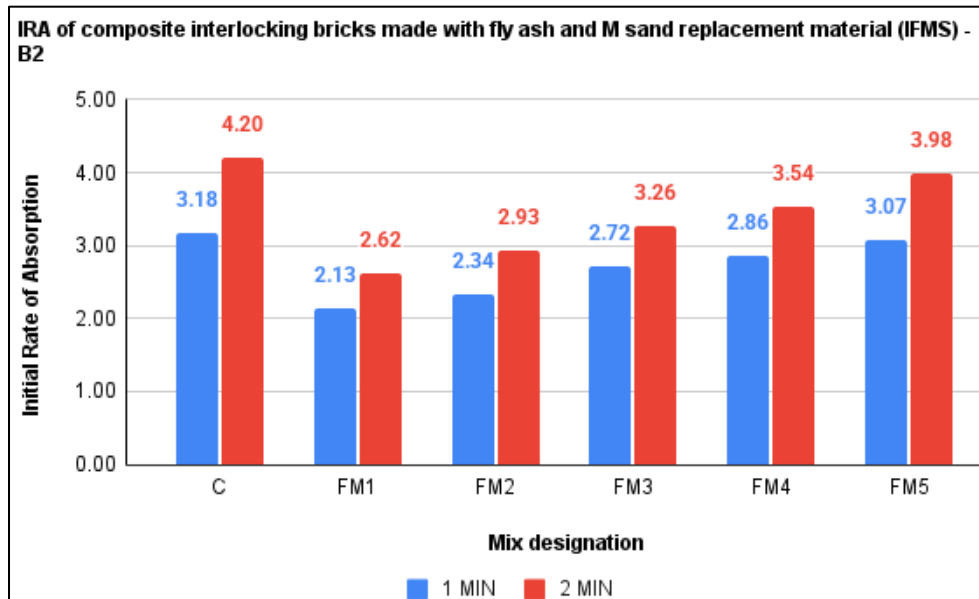


Figure 11: Initial rate of absorption of IFMS

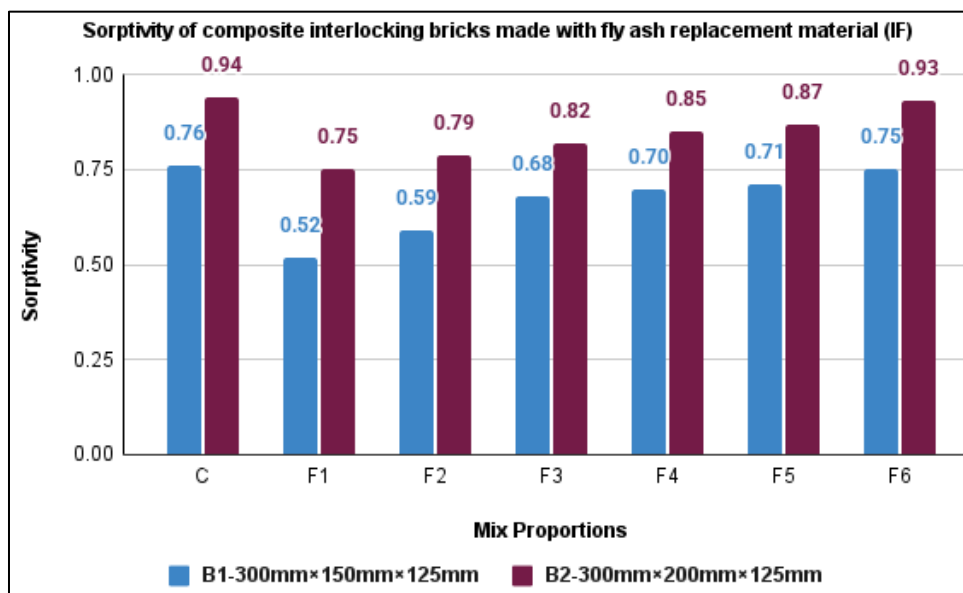


Figure 12: Sorptivity test results of IF

Figure 12 shows the sorptivity properties of composite interlocking bricks that use fly ash as a replacement material (IF) across various mix proportions (C, F1–F6). Sorptivity

values for B1 and B2 in the control mix are 0.76 and 0.94, respectively. When fly ash is added, sorptivity significantly decreases at mix F1, where the lowest values of 0.52 (B1) and

0.75 (B2) are noted. For both brick sizes, sorptivity readings progressively rise as the fly ash replacement level rises from F2 to F6, suggesting an increase in capillary water uptake.

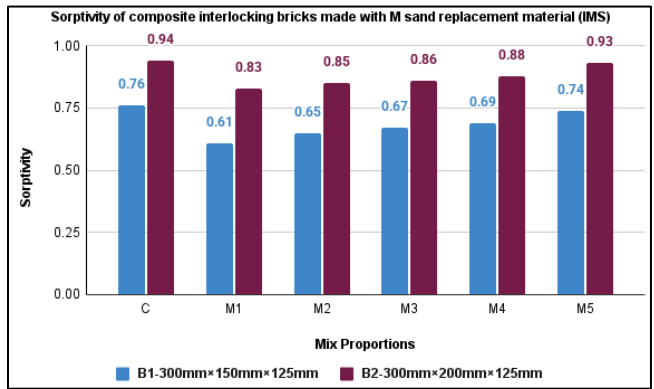


Figure 13: Sorptivity test results of IMS

Figure 13 displays the sorptivity test outcomes of bricks with M sand replacement materials (MS). Sorptivity rises as the amount of rubber in CR-substituted brick mixes (MS) increases. The range of sorptivity values for crumb rubber bricks is 0.612 to 0.742 mm³/mm²/m³ for B1 and 0.832 to 0.930 mm³/mm²/m³ for B2. At 5% and 25% CR replacement, respectively, the absorption levels are at their lowest and maximum. Capillary absorption is decreased by 19%, 15%, 11%, 8%, and 2% for B1 and 11%, 10%, 8%, 6%, and 1% for B2 when 5–25% of CR is substituted.

The sorptivity test results for bricks with combined fly ash and M sand replacement materials (FA+SD) are illustrated in Figure 14.

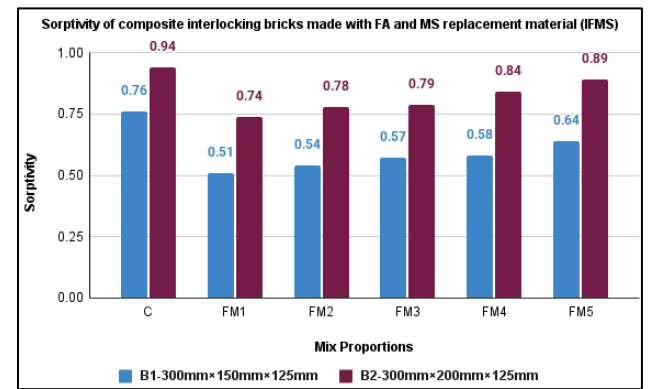


Figure 14: Sorptivity test results IFMS

The simultaneous substitution of GWP and CR (FA+MS) in bricks significantly reduces capillary absorption compared to the control mix. The GWP10CR5 mix shows a 32% reduction in capillary absorption for B1 and 21% for B2. Other mixes, including GWP20CR10, GWP30CR15, GWP40CR20, and GWP50CR25, show reductions of 28%, 25%, 23%, and 16% for B1, and 17%, 16%, 11%, and 6% for B2. However, these alternative blends exhibit higher capillary absorption compared to GWP10CR5, with increases ranging from 6% to 24% for B1 and 4% to 19% for B2.

4. CONCLUSIONS

1. Interlocking brick prepared with Flyash and 30% weighted granite waste powder shows, the highest compressive strength values of 11.82 MPa for B1 and 13.95 MPa for B2 indicate increases of roughly 44% and 31%, respectively, over the control mix.
2. Initial rate of absorption for interlocking brick made of flyash with M-sand and 25 wt % of crushed rubber show highest percentage of at 3.97% (1 min) and 4.31% (2 min) over control value.
3. At 5 wt% and 25wt % crushed rubber replacement, respectively, the absorption levels are at their lowest and maximum.
4. For both brick sizes, replacing fly ash greatly increases compressive strength up to an optimal replacement level (F3). Fly ash and M-sand work together to efficiently regulate capillary suction, especially in mixes FM1–FM3, even though higher M-sand levels often result in increased water absorption. The greater cross-sectional area and better stress distribution, bricks of size B2 continuously demonstrate stronger compressive strength and durability performance than bricks of size B1.

COMPETING INTEREST DECLARATION

The authors declare no competing interests among the authors. Moreover, there is no funding received for this research.

DATA AVAILABILITY DECLARATION

The data that support the findings of this study are available on request from the corresponding author.

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