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Performance Evaluation of Sustainable Lightweight Concrete Incorporating Recycled Brick Aggregates

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Abstract - This study investigates the performance of lightweight concrete incorporating crushed waste bricks as a partial replacement for natural coarse aggregates, focusing on optimizing the mixing proportions and evaluating the influence of silica fume content and superplasticizer dosage. The experimental results demonstrated that replacing 25% of the natural aggregates with crushed bricks improved the 28-day compressive strength, with higher cement contents mitigating the adverse effects of increased brick incorporation. The optimal silica fume content for enhancing compressive strength was identified as 15%; beyond this, the strength decreased due to reduced workability and microstructural inefficiencies. The dosage of superplasticizer significantly affected the compressive strength, with an optimum range observed at 2.0%, whereas excessive dosages resulted in strength reduction. The study also revealed that the early age compressive strength is more sensitive to brick incorporation, particularly at lower cement contents. However, mixtures with higher cement contents exhibited superior early-age strength retention. The splitting tensile strength consistently improved with increasing normal aggregate content, highlighting the role of aggregate stiffness and bond quality in controlling the tensile behavior. These findings contribute to the development of sustainable, high-performance lightweight concrete utilizing recycled materials, with potential applications in structural and non-structural elements where reduced self-weight and enhanced mechanical properties are desired.

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- *Lightweight concrete*
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- *Superplasticizer*
- *Early-age strength*
- *Splitting tensile strength*

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Introduction

Lightweight concrete (LWC) has attracted significant attention in modern construction engineering because of its ability to reduce the self-weight of structural elements while maintaining acceptable mechanical performance and durability. Unlike conventional concrete, which relies on dense natural aggregates, lightweight concrete incorporates low-density aggregates or engineered voids to achieve a reduced unit weight, typically ranging between 1400 and 2000 kg/m³ [1]. This reduction in density offers multiple structural and functional advantages, including lower dead loads, improved seismic performance, reduced foundation sizes, and enhanced thermal insulation [2]. These benefits make lightweight concrete particularly attractive for high-rise buildings, long-span structures, precast elements, and rehabilitation projects, where weight reduction is critical [3]. In addition, the increasing demand for sustainable construction materials has further reinforced the relevance of lightweight concrete, as it provides opportunities to incorporate alternative and recycled materials without compromising its performance. However, the reduction in density is often accompanied by challenges related to strength development, workability, and durability, necessitating careful mix design and material selection [4]. Consequently, extensive research has focused on optimizing lightweight concrete mixtures to balance weight reduction with the mechanical and durability requirements. The performance of lightweight concrete is highly dependent on the characteristics of its constituent materials, particularly the type, porosity, and grading of the lightweight aggregates, as well as the interaction between the aggregates and the cementitious matrix. Understanding these interactions is essential for developing lightweight concrete with predictable behavior and reliable performance in structural and nonstructural applications [5].

The construction industry is one of the largest consumers of natural resources worldwide, with natural aggregates accounting for a substantial portion of the concrete volume. Continuous sand and gravel extraction has severe environmental consequences, including the depletion of natural reserves, ecological degradation, and increased carbon emissions associated with quarrying and transportation processes [6]. In response to these concerns, sustainable construction practices have increasingly emphasized the reuse of recycled and waste materials as alternatives to conventional aggregate. The utilization of recycled aggregates derived from construction and demolition waste aligns with circular economy principles by diverting waste from landfills and reducing the reliance on virgin materials. Incorporating recycled aggregates into lightweight concrete is a promising strategy for achieving environmental sustainability and material efficiency [7]. However, recycled aggregates typically exhibit higher porosity, lower density, and greater water absorption than natural aggregates, which significantly influence the properties of fresh and hardened concrete. These characteristics can be advantageous in producing lightweight concrete but may also adversely affect its strength, stiffness, and durability if not properly controlled. Therefore, the successful replacement of natural aggregates with recycled materials requires a comprehensive understanding of their physical and chemical properties, as well as appropriate adjustments in the mix design, water demand, and admixture usage. Research efforts have increasingly focused on identifying suitable recycled aggregate sources and evaluating their performance in lightweight concrete applications to ensure compliance with the structural and durability requirements [8].

Among the various recycled materials, waste bricks generated from the construction, demolition, and

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ceramic industries have emerged as viable alternative aggregates for lightweight concrete production. Crushed waste bricks are characterized by a relatively low density, high porosity, and rough surface texture, which distinguishes them from conventional natural aggregates [9]. These properties make waste brick aggregates particularly suitable for lightweight concrete, as they contribute to density reduction while enhancing mechanical interlocking with cementitious matrices [10]. Additionally, waste bricks often contain residual amorphous and crystalline silica phases that may participate in secondary pozzolanic reactions under favorable conditions. Despite these advantages, the incorporation of crushed brick aggregates presents several technical challenges, including increased water absorption, reduced workability, and potential variability in the material quality [11]. The porous nature of brick aggregates can lead to rapid water uptake during mixing, thereby affecting the effective water-to-cement ratio and early age hydration. As a result, pretreatment methods, such as presoak or moisture conditioning, are often required to achieve consistent fresh properties. Furthermore, the replacement level of natural aggregates with crushed bricks plays a critical role in determining the balance between the weight reduction and mechanical performance. Excessive replacement ratios may result in significant strength loss, whereas optimized proportions can yield structurally viable lightweight concrete. Therefore, a systematic investigation of the waste brick aggregate content and its interaction with other mix constituents is essential for developing reliable lightweight concrete mixtures [12].

The performance of lightweight concrete incorporating recycled aggregates is strongly influenced by the adopted mixing proportions and the interactions between cementitious materials, aggregates, water, and chemical admixtures. Unlike conventional concrete, lightweight concrete mixtures require careful control of the paste volume, water content, and aggregate gradation to compensate for the higher porosity and lower stiffness of the lightweight aggregates [13]. The water-to-cement ratio plays a particularly critical role, as recycled and brick aggregates exhibit higher absorption capacities, which can significantly alter the effective water content during mixing. Improper control of the water content may lead to reduced workability, non-uniform mixing, or compromised strength development [14]. Additionally, the proportion of fine to coarse aggregates affects the particle packing density, internal curing behavior, and overall concrete homogeneity. The inclusion of supplementary cementitious materials, such as silica fume, can further modify the microstructure by refining the pore structure and improving the interfacial transition zone between aggregates and cement paste. High-range water-reducing admixtures are often necessary to maintain adequate workability at reduced water content, particularly in mixtures containing high volumes of fine or porous aggregates [12, 15]. Consequently, the optimization of mixing proportions is not only a matter of achieving the target density but also of ensuring adequate mechanical strength, durability, and consistency. Therefore, a systematic evaluation of different mixing proportions is essential to understand their combined effects on the fresh and hardened properties of lightweight concrete [16].

Despite the growing body of research on lightweight concrete and recycled aggregates, several gaps remain regarding the combined use of recycled aggregates, waste brick materials, and optimized mixing proportions of these materials. Many previous studies have focused on isolated parameters, such as single aggregate replacement levels or individual material properties, without fully addressing the synergistic effects of aggregate type, replacement ratio, and mix composition [17, 18]. In particular, limited attention has been given to

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understanding how different mixing proportions influence the lightweight characteristics, including the density, strength-to-weight ratio, and overall performance stability. Moreover, the variability in recycled material properties necessitates a comprehensive experimental approach to establish reliable correlations between the mix design parameters and concrete behavior [19]. Addressing these gaps is essential for promoting the practical adoption of lightweight concrete incorporating recycled aggregates in structural and nonstructural applications [20]. Therefore, this study aims to investigate lightweight concrete produced by replacing conventional natural aggregates with recycled aggregates and crushed waste bricks, while systematically examining the influence of different mixing proportions on the fresh and hardened properties. By providing a detailed evaluation of material interactions and performance outcomes, this study contributes to the development of sustainable, resource-efficient lightweight concrete with predictable and reproducible properties suitable for modern construction practices [21, 22].

The study investigates sustainable lightweight concrete using crushed waste brick aggregates as a partial replacement for natural coarse aggregates, focusing on optimizing mix proportions with silica fume and superplasticizer. This study fills gaps in understanding the synergistic effects of recycled aggregate type, replacement ratio, and mix design on lightweight concrete performance, providing a systematic experimental evaluation of these factors.

Experimental program

A. *Raw materials*

The raw materials used for producing lightweight concrete incorporating crushed brick as a partial replacement for natural coarse aggregate consisted of ordinary Portland cement, natural fine aggregate (sand), crushed brick aggregate, silica fume, and a high-range water-reducing agent. Ordinary Portland cement, conforming to the relevant ASTM specifications, was used as the primary binding material, as shown in **Fig. 1.** Natural river sand with appropriate grading and cleanliness was used as the fine aggregate to ensure adequate workability and packing density. Crushed brick waste, obtained from construction and demolition residues, was utilized as a lightweight coarse aggregate replacement owing to its lower density and rough surface texture, which enhances mechanical interlocking with the cement matrix. Silica fume, composed mainly of amorphous silicon dioxide (SiO_2), was incorporated as a highly reactive pozzolanic material to improve the microstructure, reduce porosity, and enhance the mechanical and durability properties of lightweight concrete. Its quality complies with the ASTM C1240 and AASHTO M 307 specifications. To compensate for the high-water demand associated with silica fume and crushed brick aggregates, a naphthalene sulfonate-based superplasticizer supplied by CMB under the trade name Addicrete BVF was used. This admixture meets the requirements of ASTM C494 Types F and G as well as BS EN 934-2:2001, and it was effective in achieving the desired workability at a reduced water-to-cement ratio without adversely affecting the setting characteristics of the concrete.

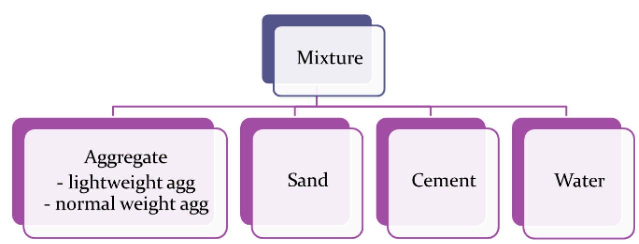

Fig. 1. Raw materials

B. *Mixing procedures*

The mixing procedure was conducted in a controlled and sequential manner to ensure proper homogeneity of the lightweight concrete mixture and mitigate the negative effects associated with the high porosity of the crushed brick aggregates and the ultra-fine nature of the silica fume. Before mixing, the crushed brick coarse

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aggregates were washed to remove adhered dust and then pre-soaked in water for 24 h to reduce excessive water absorption during mixing. Before use, the aggregates were brought to a saturated surface-dry (SSD) condition. The mixing was performed using a laboratory pan mixer. Initially, all dry constituents, including ordinary Portland cement, silica fume, and natural fine aggregate, were dry mixed for approximately 3 min to achieve uniform distribution and prevent agglomeration of silica fume particles. Subsequently, the crushed brick aggregates were added gradually and mixed for an additional 2 min to ensure even coating with the cementitious materials.

The mixing water was divided into two portions; approximately 70% of the total mixing water was added slowly while mixing continued for 2 min to initiate hydration and improve particle packing. The remaining 30% of the water was premixed with the naphthalene sulfonate-based superplasticizer and introduced gradually into the mixture to enhance dispersion and workability. The concrete was then mixed for an additional 3–5 min until a homogeneous, cohesive mixture with no visible segregation or bleeding was obtained. After mixing, the fresh concrete was allowed to rest for approximately 1 min before casting to allow air release and stabilization of the mixture. This mixing protocol ensured consistent fresh-state properties and reproducible hardened performance of lightweight concrete. **Tabs. 1-4** shows the designed experimental program and mixing proportions.

Tab. 1. Designed experimental program

w/c	cement	N.w / L.w aggregate	Super plasticizer	Silica fume + 0.2%SP
• 0.5 • 0.4	• 400 • 450 • 500	• 0% • 25% • 50% • 70% • 100%	• 0% • 0.5% • 1% • 1.5% • 2% • 2.5% • 3%	• 0% • 10% • 15% • 20% • 30%

Tab. 2. mixing proportions G1

Mix	Cement	W/C	Sand	N.w./L.w. (%)	Silica fume	S.P./C (%)
B40-5-0	400	0.5	583	0	0	0
B40-5-25				25		
B40-5-50				50		
B40-5-75				75		
B40-5-100				100		
B40-4-0		0.4	619	0		
B40-4-25				25		
B40-4-50				50		
B40-4-75				75		
B40-4-100				100		
B45-5-0	450	0.5	549	0	0	0
B45-5-25				25		
B45-5-50				50		
B45-5-75				75		
B45-5-100				100		
B45-4-0		0.4	588	0		
B45-4-25				25		
B45-4-50				50		
B45-4-75				75		
B45-4-100				100		
B50-5-0	500	0.5	512	0	0	0
B50-5-25				25		
B50-5-50				50		
B50-5-75				75		
B50-5-100				100		
B50-4-0		0.4	556	0		
B50-4-25				25		
B50-4-50				50		
B50-4-75				75		
B50-4-100				100		

Tab. 3. mixing proportions G2

Mix	Cement	W/C	Sand	N.w./L.w. (%)	Silica fume	S.P./C (%)
BA0	450	0.3	586	25	0	0.00%
BA0.5						0.50%
BA1						1%
BA1.5						1.50%
BA2						2%
BA2.5						2.50%
BA3						3%

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Tab. 4. mixing proportions G3

<table>
<tr><th>Mix</th><th>Cement</th><th>W/C</th><th>Sand</th><th>N.w./L.w. (%)</th><th>Silica fume</th><th>S.P./C (%)</th></tr>
<tr><td>BAF10</td><td rowspan="4">450</td><td>0.3</td><td rowspan="4">586</td><td rowspan="4">25</td><td>10%</td><td>2%</td></tr>
<tr><td>BAF15</td><td>0.3</td><td>15%</td><td>2%</td></tr>
<tr><td>BAF20</td><td>0.3</td><td>20%</td><td>2%</td></tr>
<tr><td>BAF30</td><td>0.3</td><td>30%</td><td>2%</td></tr>
</table>

Fig. 2. Testing procedures

Mixing procedures

All tests were conducted following relevant ASTM standards to ensure the accuracy and reliability of the experimental results. The concrete was cast into standard steel molds in accordance with ASTM specifications. For compressive strength testing, cubic or cylindrical specimens were prepared and compacted using mechanical vibration to eliminate entrapped air and ensure uniform density. After casting, the specimens were covered and kept at room temperature for 24 hours before demolding. The demolded specimens were then cured in water at a controlled temperature until the designated testing ages of 7 and 28 days. Compressive strength tests were carried out using a calibrated universal testing machine by applying a continuous and uniform load at the specified loading rate until failure occurred, and the maximum load was recorded. Splitting tensile strength tests were performed on cylindrical specimens following ASTM C496, where the load was applied diametrically until splitting failure was observed. For each mix, at least three specimens were tested at each curing age, and the average value was reported to ensure result consistency and minimize experimental variability. **Fig.2** shows some procedures during testing

Results and discussion

A. Effect of SF

The effect of the silica fume content on the compressive strength of the lightweight concrete mixtures is illustrated in **Fig.3** and summarized in the corresponding mix proportions shown in **Tab 4.** The results demonstrated a clear influence of the silica fume replacement level on both early- and later-age compressive strengths. At 7 and 28 d, the compressive strength exhibited a progressive increase with increasing silica fume content up to 15%, followed by a noticeable reduction at higher replacement levels. The reference mixture containing 10% silica fume (BAF10) showed moderate compressive strength values, whereas increasing the silica fume content to 15% (BAF15) resulted in the highest compressive strength at both curing ages. This improvement can be attributed to the high pozzolanic reactivity of the silica fume, which enhances the formation of additional calcium silicate hydrate (C–S–H) gel and refines the pore structure, particularly in the interfacial transition zone between the cement paste and the lightweight aggregate. However, further increasing the silica fume content to 20% and

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30% (BAF20 and BAF30) led to a reduction in compressive strength, despite maintaining a constant water-to-cement ratio and superplasticizer dosage. This decline is primarily associated with the excessive fineness of the silica fume, which increases the water demand and may result in inadequate dispersion and particle agglomeration when used in high proportions. Consequently, the effectiveness of silica fume in improving strength diminishes beyond the optimum replacement level. Moreover, although the 28-day compressive strength values were consistently higher than the corresponding 7-day results for all mixtures, the same trend of optimal performance at 15% silica fume was observed. These findings indicate that an optimal silica fume content exists for lightweight concrete incorporating recycled aggregates, beyond which the beneficial effects on compressive strength are outweighed by the adverse effects related to workability and microstructural inefficiencies.

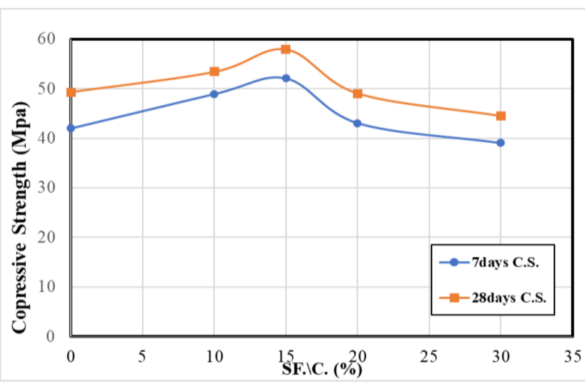

Fig. 3. compressive strength for G3

B. *Effect of SP*

Fig. 4 illustrates the influence of superplasticizer dosage (SP/C%) on the compressive strength of lightweight concrete mixtures at 7 and 28 days, with the corresponding mix proportions presented in **Tab. 3.** The results indicate that the compressive strength is significantly affected by the superplasticizer content, which exhibits a clear optimum range. At both curing ages, a gradual increase in compressive strength was observed with an increase in the SP/C ratio up to 2.0%, after which a noticeable reduction occurred at higher dosages. The control mixture without the superplasticizer (BA0) exhibited the lowest compressive strength, primarily owing to inadequate workability and incomplete compaction, which negatively affected the internal structure of the concrete. The introduction of small amounts of superplasticizer (0.5–1.5%) led to a marked improvement in compressive strength, which was attributed to enhanced workability, improved particle dispersion, and more efficient cement hydration at a constant water-to-cement ratio.

The optimum performance was achieved at a superplasticizer dosage of 2.0% (BA2), which recorded the highest compressive strength values at both 7 d and 28 d. This behavior can be explained by the ability of the superplasticizer to reduce internal friction, improve paste fluidity, and enhance the homogeneity of the lightweight concrete mixture, particularly when porous recycled aggregates are present. However, further increasing the superplasticizer content to 2.5% and 3.0% (BA2.5 and BA3, respectively) reduced the compressive strength. This decrease is likely due to excessive dispersion and segregation tendencies, as well as possible retardation effects that adversely influence the formation of dense cementitious matrices. Although the 28-day compressive strength values were consistently higher than those at 7 days for all mixtures, the same trend of optimal performance at 2.0% superplasticizer dosage was observed. These results confirm that the superplasticizer content must be carefully optimized in lightweight concrete mixtures to achieve a balance between workability enhancement and mechanical performance.

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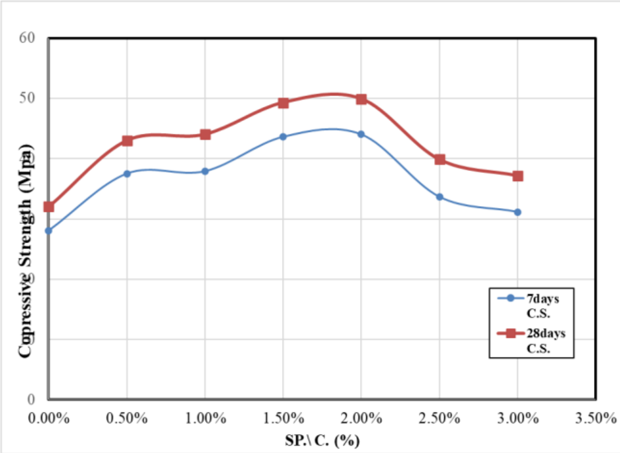

Fig. 4. compressive strength for G2

C. *Early compressive strength*

Fig. 5 illustrates the effect of the crushed brick replacement ratio on the 7-day compressive strength of the lightweight concrete mixtures with different cement contents (400, 450, and 500 kg/m³). For mixtures with a cement content of 400 kg/m³, replacing 25% of the natural aggregate with crushed bricks increased the compressive strength from 28.05 MPa to 30.27 MPa, corresponding to an improvement of approximately 7.9%. However, increasing the replacement level to 50% resulted in a reduction to 25.61 MPa, representing a strength loss of approximately 8.7% compared to the control mix. A more pronounced decrease of approximately 11.0% was observed at 75% replacement (24.97 MPa), whereas a slight recovery occurred at full replacement (100%), with a strength of 27.10 MPa, indicating a marginal reduction of 3.4% relative to the reference mixture.

A similar trend was observed for mixtures containing 450 kg/m³ of cement. The 7-day compressive strength increased from 36.35 MPa to 33.98 MPa at 25% replacement, showing a reduction of approximately 6.5%, indicating that early age strength development is more sensitive to brick incorporation at this cement content. Further increases in brick replacement led to strength reductions of approximately 9.2%, 19.1%, and 25.5% at 50%, 75%, and 100% replacement levels, respectively.

In contrast, mixtures with the highest cement content (500 kg/m³) demonstrated superior early age strength. A 25% crushed brick replacement increased the compressive strength from 37.93 MPa to 38.92 MPa, achieving an improvement of approximately 2.6%. At higher replacement levels, the strength reductions were limited to 9.3% at 50% replacement, 17.7% at 75% replacement, and 18.3% at 100% replacement. These results confirm that moderate crushed brick replacement ratios, particularly approximately 25%, can enhance or maintain early age compressive strength, whereas higher cement contents effectively mitigate the adverse effects of increased brick aggregate incorporation at early curing ages.

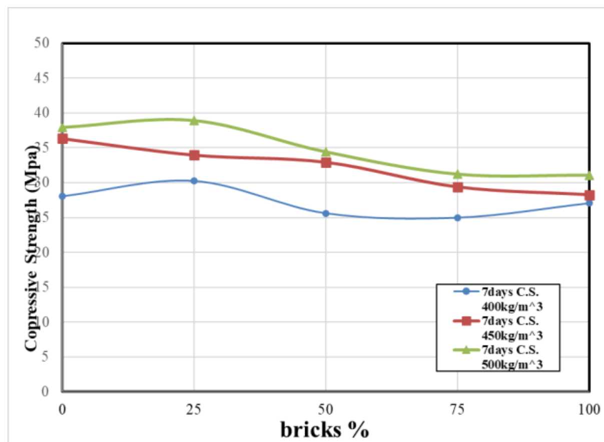

Fig. 5. Early compressive strength for G1

D. *28 days compressive strength*

The percentage improvement in the 28-day compressive strength resulting from the partial replacement of natural aggregates with crushed bricks is illustrated in Fig.6. For mixtures with a cement content of 400 kg/m³, replacing 25% of natural aggregate with crushed bricks led to an increase in compressive strength from approximately 35 MPa to 37 MPa, corresponding to an improvement of approximately 5.7%. However, further increasing the replacement level

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to 50% resulted in a strength reduction of nearly 8.6%, whereas a more pronounced decrease of approximately 14.3% was observed at 75% replacement. At full replacement (100%), the compressive strength partially recovered, showing a reduction of only 2.9% compared with the reference mix.

For mixtures containing 450 kg/m³ cement, the beneficial effect of crushed brick replacement was evident. A 25% replacement level increased the compressive strength from approximately 42 MPa to 44 MPa, representing an improvement of approximately 4.8%. In contrast, strength reductions of approximately 7.1% and 11.9% were recorded at 50% and 75% replacement levels, respectively. At 100% brick replacement, the compressive strength decreased by approximately 4.8%, indicating better strength retention than that of mixtures with lower cement contents.

The mixtures with the highest cement content (500 kg/m³) exhibited the most stable behavior. A 25% crushed brick replacement increased the compressive strength from nearly 45 MPa to 47 MPa, achieving an improvement of approximately 4.4%. Even at higher replacement levels, the strength loss remained relatively limited, with reductions of approximately 2.2%, 11.1%, and 6.7% at 50%, 75%, and 100% replacement levels, respectively. These results confirm that a moderate crushed brick replacement level of approximately 25% provides optimum mechanical performance, whereas higher cement contents significantly mitigate the adverse effects of increased brick aggregate incorporation.

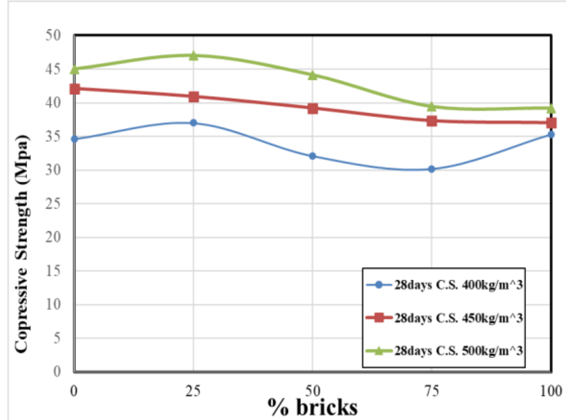

Fig. 6. 28 days compressive strength for G1

E. Early tensile strength

Fig. 7 shows tensile strength of the lightweight concrete mixtures with cement contents of 400 and 450 kg/m³. For mixtures containing 400 kg/m³ cement, the tensile strength gradually increased with increasing normal aggregate content. The reference mixture with 0% normal aggregates recorded a tensile strength of approximately 2.0 MPa. Increasing the normal aggregate content to 25% resulted in a slight reduction of approximately 1.95 MPa, corresponding to a marginal decrease of approximately 2.5%, which may be attributed to local heterogeneity at low replacement levels. However, at 50% replacement, the tensile strength increased to approximately 2.2 MPa, representing an improvement of approximately 10.0% compared to the reference mixture. A significant enhancement was observed at 75% normal aggregate content, where the tensile strength reached approximately 3.0 MPa, corresponding to an improvement of nearly 50.0%. At full replacement (100%), the tensile strength further increased to approximately 3.2 MPa, achieving a maximum improvement of approximately 60.0% relative to the lightweight aggregate mixture.

Similarly, mixtures with a higher cement content of 450 kg/m³ demonstrated consistently higher tensile strength values at all replacement levels. The reference mixture

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recorded a tensile strength of approximately 2.8 MPa, which increased slightly to approximately 2.85 MPa at 25% replacement, corresponding to an improvement of approximately 1.8%. At 50% normal aggregate content, the tensile strength increased to approximately 3.1 MPa, representing an improvement of approximately 10.7%. Further increases to 75% and 100% normal aggregates resulted in tensile strengths of approximately 3.25 MPa and 3.35 MPa, corresponding to improvements of approximately 16.1% and 19.6%, respectively. The observed enhancement in tensile strength with increasing normal aggregate content can be attributed to the higher stiffness and lower porosity of normal aggregates, which improve the crack resistance and strengthen the interfacial transition zone, particularly at early curing ages.

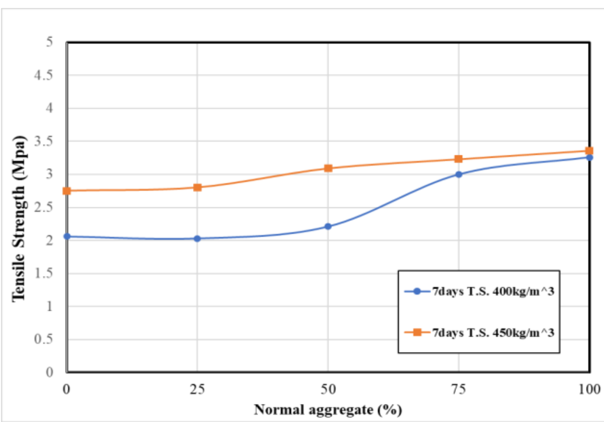

Fig. 7. Early tensile strength for G1

F. 28 days tensile strength

Fig.8 illustrates the variation in splitting tensile strength of lightweight concrete as a function of normal aggregate percentage for mixtures with cement contents of 400 and 450 kg/m³ at 28 d and 7 d, respectively. The results revealed a clear and consistent improvement in the tensile strength with increasing normal aggregate content, indicating the significant role of aggregate stiffness and bond quality in controlling the tensile behavior. For mixtures with a cement content of 400 kg/m³ tested at 28 d, increasing the normal aggregate content from 0% to 25% resulted in a marginal increase in tensile strength from approximately 2.9 MPa to 2.95 MPa, corresponding to an improvement of approximately 1.7%. A more noticeable enhancement was observed at 50% normal aggregate content, where the tensile strength increased to approximately 3.2 MPa, representing an improvement of approximately 10.3% compared with the reference mix. Further increasing the normal aggregate content to 75% led to a significant increase in the tensile strength to nearly 3.9 MPa, corresponding to an improvement of approximately 34.5%. At full replacement (100%), the tensile strength reached approximately 4.0 MPa, achieving a maximum improvement of approximately 37.9% relative to the mixture containing only lightweight aggregates.

Similarly, for mixtures with a cement content of 450 kg/m³ tested at 7 d, a continuous increase in tensile strength was observed with increasing normal aggregate percentage. The tensile strength increased from approximately 3.6 MPa at 0% normal aggregate to approximately 3.7 MPa at 25%, indicating an improvement of approximately 2.8%. At 50% normal aggregate content, the tensile strength reached nearly 3.9 MPa, corresponding to an improvement of approximately 8.3%. Further increases to 75% and 100% normal aggregates resulted in tensile strengths of approximately 4.0 MPa and 4.3 MPa, representing improvements of approximately 11.1% and 19.4%, respectively. These results confirm that incorporating higher proportions of normal aggregates enhances tensile resistance by improving crack-bridging capacity and strengthening the interfacial transition zone, while mixtures with lower normal aggregate content exhibit reduced tensile performance owing to the higher porosity and lower stiffness of the lightweight aggregates.

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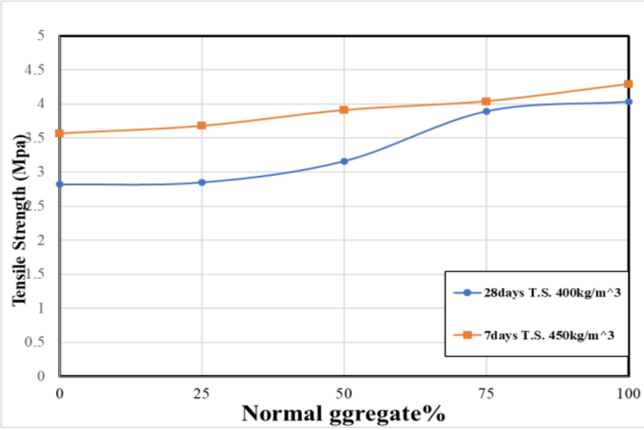

Fig. 8. 28 daya tensile strength for G1

Conclusion

This study demonstrates that incorporating crushed waste brick aggregates as a partial replacement for natural coarse aggregates in lightweight concrete can enhance its mechanical performance and sustainability. The optimal mixing proportions, including the silica fume content and superplasticizer dosage, are critical for achieving improved compressive and tensile strengths. Moderate replacement levels (approximately 25%) and higher cement contents effectively balanced strength gains with the benefits of reduced density. These findings support the practical use of recycled brick aggregates in lightweight concrete, contributing to resource efficiency and environmental sustainability in construction.

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