DURABILITY AND INTERNAL CURING PERFORMANCE OF ROLLER COMPACTED CONCRETE INCORPORATING BRICK FINE AGGREGATE AS RECYCLED MATERIAL

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ABSTRACT

Roller Compacted Concrete (RCC) is susceptible to self-desiccation due to its low water-to-cement ratio, which prematurely limits cement hydration, while its dense zero-slump matrix reduces the effectiveness of conventional surface curing. This study investigates the use of Brick Fine Aggregate (BFA) as a partial replacement for natural fine aggregate in RCC, with emphasis on internal curing potential and abrasion resistance. BFA obtained from locally demolished masonry structures exhibited a 72-hour water absorption of 19.74% and a desorption capacity of 86.8%, confirming its suitability as an internal curing aggregate. Replacement levels of 10%, 15%, and 20% were systematically determined based on internal curing water demand, unlike previous studies that adopted empirically selected replacement levels. The RCC mix was designed in accordance with soil compaction principles, with a fixed cementitious content of 12%. Compressive strength was evaluated at 3, 7, and 28 days, while underwater abrasion resistance was assessed over 72 hours. The control mix achieved a 28-day compressive strength of 40.70 MPa. The 20% BFA mix yielded a 63% improvement in 3-day strength and achieved 37.15 MPa at 28 days, while the 10% mix recorded the lowest strength of 27.00 MPa. The 15% BFA mix recorded the highest abrasion loss, approximately 91% greater than the control, while the 10% and 20% BFA mixes recorded cumulative volume losses approximately 44% and 46% greater than the control respectively, confirming that enhanced paste densification through internal curing at 20% replacement compensates for the mechanical weakness of brick aggregate. Overall, 20% BFA replacement demonstrated the most favorable durability performance, confirming that brick C&D waste can be effectively utilized in RCC as both a recycled aggregate and an internal curing agent for sustainable pavement construction.

Keywords: roller compacted concrete, brick fine aggregate, internal curing, abrasion resistance, recycled aggregate.

1. INTRODUCTION

Roller Compacted Concrete (RCC) is widely used in pavements, dams, and industrial applications due to its rapid construction, cost-effectiveness, and durability (Harrington et al., 2010). However, its low water-to-cement ratio induces rapid self-desiccation, reducing internal relative humidity and prematurely limiting cement hydration, while the dense zero-slump matrix restricts penetration of externally applied curing water. Brick waste constitutes approximately 30–50% of construction and demolition (C&D) waste by weight in developing countries. Due to their high porosity and elevated water absorption capacity, brick aggregates can function as internal curing agents by gradually releasing stored water during cement hydration, improving hydration efficiency and long-term durability, while simultaneously reducing landfill disposal and excessive extraction of natural aggregates.

Previous studies have mainly focused on the mechanical properties of BFA-incorporated RCC, with limited attention given to abrasion resistance and no systematic determination of replacement levels based on internal curing water demand. The primary methodological contribution of this study is the determination of BFA replacement levels of 10%, 15%, and 20% directly from the internal curing water demand of the RCC matrix, calculated in accordance with ASTM C1761/C1761M. This differs from prior studies where replacement levels were selected

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empirically. Building on this contribution, the study investigates the compressive strength and abrasion resistance of BFA-incorporated RCC for sustainable pavement applications.

2. LITERATURE REVIEW

2.1 Roller-Compacted Concrete and Recycled Aggregates

Previous studies have investigated the use of recycled materials such as recycled concrete aggregate (RCA), ceramic tile waste, and brick waste in RCC. Khalid and Abbas (2023) reported that RCA reduced compressive strength due to increased porosity and a weaker interfacial transition zone (ITZ). Tavakoli et al. (2022) found that brick waste replacement up to 25% did not significantly affect RCC performance, although higher replacement levels caused deterioration. However, replacement levels were selected empirically rather than based on internal curing water demand. Al-Ani and Abbas (2025) reported strength improvements with brick waste replacement but did not comprehensively evaluate abrasion resistance.

2.2 Internal Curing and Abrasion Resistance in RCC

Internal curing involves the use of pre-wetted porous aggregates to provide additional water for continued cement hydration. This mechanism is particularly beneficial in RCC, where the dense zero-slump matrix restricts external curing water penetration. Jayantha et al. (2025) confirmed that clay tile waste improved early-age compressive strength in RCC through internal curing, while Rao et al. (2016) established that improved hydration quality reduces abrasion loss. However, no previous study has investigated the abrasion resistance of BFA-incorporated RCC at replacement levels systematically determined based on ASTM C1761/C1761M internal curing requirements.

3. METHODOLOGY

3.1 Materials and Preparation of Brick Fine Aggregate

Brick waste obtained from demolished masonry structures was cleaned, air-dried, and crushed to produce Brick Fine Aggregate (BFA). Combined aggregate gradation was developed using chips, quarry dust, natural coarse aggregate, and natural fine aggregate, and adjusted to remain within RCC gradation limits. Water absorption, relative density, and desorption characteristics of BFA were evaluated following ASTM C1761/C1761M to assess its suitability as an internal curing aggregate.

3.2 RCC Mix Design and Internal Curing Requirement

The RCC mix was designed based on ACI 327R-14 guidelines using soil compaction principles with a fixed cementitious content of 12%. The Modified Proctor Compaction Test was conducted according to ASTM D1557 to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). BFA replacement levels of 10%, 15%, and 20% were determined based on internal curing water demand in accordance with ASTM C1761/C1761M.

3.3 Specimen Preparation, Curing, and Testing

RCC specimens were compacted using a vibrating hammer in accordance with ASTM C1435/C1435M. Control specimens were externally water cured for 7 days, while BFA-modified specimens relied solely on internal curing through pre-wetted BFA particles. Compressive strength tests were conducted at 3, 7, and 28 days following ASTM C39/C39M, with three replicate cylinders tested at each age for each mix, and the mean value reported. Underwater abrasion resistance was evaluated using ASTM C1138 over a 72-hour period by measuring cumulative volume loss and average abrasion depth. One specimen was tested for each mix proportion due to the long test duration and equipment limitations; therefore, the abrasion results are interpreted as comparative trends.

4. RESULTS AND DISCUSSION

4.1. Material Characterization

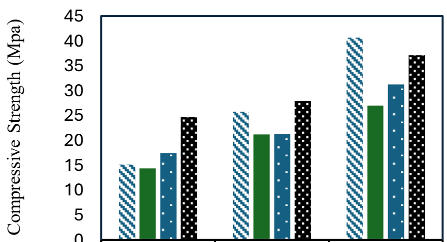
BFA exhibited a 72-hour water absorption of 19.74%, significantly higher than natural coarse aggregate (0.95%) and fine aggregate (1.20%), substantially exceeding the 5% minimum threshold specified in ASTM C1761/C1761M for internal curing aggregates. The oven-dry relative density of BFA (1.84) was considerably lower than that of natural aggregates (2.41–2.71), consistent with its higher porosity. The desorption capacity was 86.8%, with approximately 83% of absorbed water released within the first two days, coinciding with the most active period of cement hydration, confirming the suitability of BFA as an internal curing aggregate.

4.2. Compressive Strength

Compressive strength results are presented in Figure . The control mix achieved a 28-day strength of 40.70 MPa. The 20% BFA mix yielded a 63% improvement in three-day strength over the control through sustained internal moisture release, achieving 37.15 MPa at 28 days. The 15% mix recorded 31.25 MPa, whilst the 10% mix recorded the lowest value of 27.00 MPa, attributed to both a weakened interfacial transition zone and insufficient internal curing water to compensate for self-desiccation. A cross-over trend was observed, where BFA-modified mixes exhibited superior early-age strength but lower later-age strength than the control, as internal curing benefits diminished with age.

4.3. Abrasion Resistance

Cumulative volume loss due to abrasion is presented in Figure **.** The control specimen recorded the lowest volume loss, indicating the highest abrasion resistance. The 15% BFA mix recorded the highest material loss, approximately 91% greater than the control, attributable to an unfavorable intermediate condition where BFA content is sufficiently high to introduce weak aggregate interfaces, yet internal curing water remains insufficient to achieve the paste densification attained at 20% replacement. The 10% and 20% mixes performed comparably, confirming that enhanced paste densification through internal curing at higher replacement levels compensates for the mechanical weakness of brick aggregate.



	3 day	7 day	28 day
Control Sample	15.15	25.8	40.7
10% BFA	14.35	21.23	27
15% BFA	17.45	21.35	31.25
20% BFA	24.7	27.9	37.15

Figure 1. Compressive strength test results

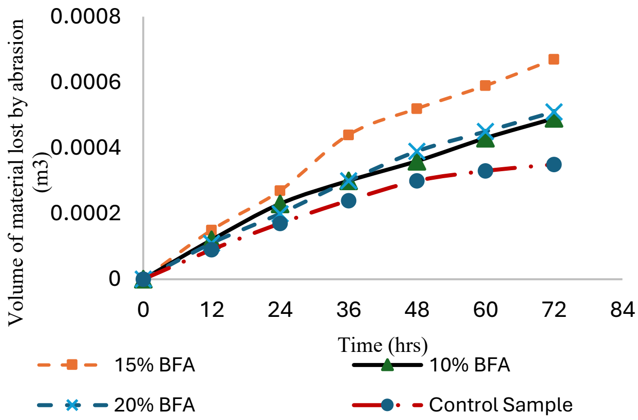


Figure 2. Volume loss due to abrasion over time for different BFA replaced RCC specimens

5. CONCLUSION

BFA was confirmed as a suitable internal curing aggregate, with a water absorption of 19.74% and a desorption capacity of 86.8%. Critically, the 10%, 15%, and 20% replacement levels were derived directly from the internal curing water demand per ASTM C1761/C1761M, distinguishing this study from prior work where replacement levels were empirically selected. The 20% BFA replacement demonstrated the most favorable overall durability performance, delivering a 63% improvement in three-day compressive strength and abrasion resistance comparable to the 10% mix. This performance was governed by the balance between internal curing effectiveness and aggregate mechanical characteristics rather than either factor independently. The 15% mix is not recommended due to poor abrasion resistance, whilst the 10% mix is not recommended due to insufficient compressive strength and insufficient internal curing. These findings confirm that brick C&D waste can be effectively utilized in RCC as both a recycled aggregate and an internal curing agent, offering a viable and sustainable pathway for pavement construction. It should be noted that brick demolition waste properties vary considerably by source, and this material variability should be considered in field implementation. Future work should investigate field-scale performance, permeability, shrinkage, freeze–thaw resistance, optimized aggregate packing and gradation, and the combined effect of BFA with supplementary cementitious materials.

6. REFERENCES

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