

Interface Durability of ECC Repairs on Concrete Structures Subjected to Dry-Wet Cycles

Balitebya Gloire Malirwa*, Hirwa Ibrahim

Department School of Urban Construction, Changzhou University, Changzhou, China

*Corresponding author details: Balitebya Gloire Malirwa; malirwagloire@gmail.com

ABSTRACT

The study investigated the durability and effectiveness of Engineered Cementitious Composite (ECC) repair interfaces when applied to damaged concrete structures and exposed to alternating dry and wet conditions. In the context of such fluctuating environmental conditions, the superior mechanical properties of ECC do not necessarily protect the repair-substrate interface from degradation. The study uses systematic experimental testing methods along with parametric analysis to investigate the performance factors of the interface, such as mix design and surface preparation, and curing techniques. Bond strength between interfaces depends heavily upon surface topography, together with pre-treatment methods and polymeric additives added to ECC materials. The microscopic examination shows that interface failures occur because moisture transport affects the interface, together with the different rates of shrinkage between the repair materials and the base materials. The study's findings provide practical solutions to enhance ECC repair durability through improved surface prep techniques and modified mixtures, and effective curing methods. Such research findings are applicable in advancing the development process of durable concrete repair methods for structures exposed to changing environmental conditions.

Keywords: Engineered Cementitious Composites; concrete repair; interface durability; dry-wet cycles; bond strength.

INTRODUCTION

The deterioration of concrete infrastructure is a worldwide challenge, considering the resources that ought to be allocated for maintenance and repair expenses every year. According to Li (2003), Engineered Cementitious Composites (ECC), a special class of fiber-reinforced cementitious materials characterized by strain-hardening behavior and tight crack width control, has emerged as a promising material for concrete repairs. While the mechanical properties of ECC have been extensively studied and proven superior to conventional repair mortars, the long-term durability of the interface between ECC repairs and existing concrete substrates remains a critical concern (Sahmaran et al., 2009).

The repair systems face exceptional difficulties when dealing with infrastructure that experiences periodic environmental changes through dry-wet cycles. Multiple drying-wetting cycles create intricate stress conditions at repair-substrate junctions, resulting from differences in volumetric changes and water gradients, and hydration material loss (Qian et al., 2009). The application of cutting-edge repair materials has not eliminated interface junction failures, which significantly reduces the operational duration of repaired structures.

Through systematic review of previous relevant literature, experimental testing, and parametric analysis, this study investigated the interface durability of ECC repairs on concrete substrates subjected to dry-wet cycles. Through comprehensive experimental testing and microstructural analysis, the study sought to identify key factors affecting ECC durability. In addition to identifying such factors, the study quantified the factors affecting interface performance under cyclic environmental conditions and analyzed the microstructural evolution at the repair-substrate interface. In order to establish feasible and actionable recommendations, the study validated practical methodologies for improving interface durability through optimized material design and application techniques. Therefore, the main study objectives were:

- To evaluate the interface durability of ECC repairs on existing concrete structures subjected to dry-wet cycles through comprehensive experimental testing.
- To propose evidence-based recommendations for enhancing the longevity of ECC repair systems in field applications.

LITERATURE REVIEW

Engineered Cementitious Composites

Engineered Cementitious Composites (ECC) represent a class of high-performance fiber-reinforced cementitious materials designed with micromechanics-based principles to achieve strain-hardening behavior under tension (Li, 1998). Unlike conventional fiber-reinforced concrete, ECC exhibits multiple cracking with controlled crack widths typically below 100 μm , even under large deformation (Yang et al., 2007). This unique property stems from the carefully engineered interaction between the cementitious matrix and deliberately selected fibers, typically polyvinyl alcohol (PVA) or polyethylene (PE) fibers at moderate volume fractions (1-2%) (Revilla-Cuesta et al., 2024).

The superior mechanical properties of ECC include tensile strain capacity of 3-5%, compared to 0.01-0.02% for normal concrete (Li et al., 2001). This exceptional ductility, coupled with moderate tensile strength (4-6 MPa), makes ECC particularly suitable for repair applications where deformation compatibility between repair material and substrate is critical (Şahmaran and Li, 2009).

Interface Bonding in Concrete Repairs

The durability of concrete repairs hinges significantly on the quality of the bond between the repair material and the substrate. This bond is influenced by numerous factors, including surface preparation, mechanical interlocking, adhesion, and chemical bonding (Julio et al., 2004). Surface roughness plays a particularly crucial role, with studies indicating that increased roughness generally leads to improved bond strength due to enhanced mechanical interlocking (Garbacz et al., 2005).

The interface transition zone (ITZ) between repair material and substrate concrete represents a microstructurally distinct region characterized by higher porosity and different hydration products compared to the bulk materials (Sahmaran et al.,

2013). This zone often becomes the weakest link in repair systems, especially when subjected to environmental loading (Sun et al., 2022).

Effects of Dry-Wet Cycles on Repair Systems

Dry-wet cycles represent one of the most detrimental environmental conditions for concrete repair durability. These cycles induce significant stresses at the repair-substrate interface due to differential shrinkage, swelling, and moisture gradient-induced warping (Zhang et al., 2012). During wet cycles, moisture absorption leads to expansion and potential leaching of calcium hydroxide, while dry cycles cause shrinkage and potential salt crystallization (Li and Li, 2009).

Previous research has demonstrated that cyclic wetting and drying can reduce interface bond strength by up to 60% after prolonged exposure (Qian et al., 2014). This degradation is attributed to the formation of microcracks, increased porosity at the interface, and potential chemical degradation of hydration products (Zhang et al., 2013).

Gaps in Current Knowledge

While extensive research exists on ECC material properties and general repair durability, systematic studies focusing specifically on the interface durability of ECC repairs under dry-wet cycles remain limited. Most existing studies focus on mechanical properties under static conditions, with insufficient attention to long-term durability under cyclical environmental loading (Li et al., 2021). Additionally, comprehensive guidelines for optimizing ECC mix design and application techniques specifically for enhanced interface durability are lacking in the current literature.

EXPERIMENT

ECC specimens were used to set up an experiment designed to systematically investigate the interface durability of ECC repairs under dry-wet cycles. Table 1 illustrates the overall experimental procedures and activities undertaken.

TABLE 1: Schematic Overview of The Experiment.

	Activities	Description
Step 1	Materials Preparation	<ul style="list-style-type: none"> Substrate concrete Four ECC mixtures
Step 2	Surface Preparation	<ul style="list-style-type: none"> Grinding (G) Sand-blasting (SB) Hydro-jetting (HJ)
Step 3	Specimen Preparation	<ul style="list-style-type: none"> Dry substrate (D) Pre-wetted substrate (W) 24 combinations total
Step 4	Curing	<ul style="list-style-type: none"> 28 days at 23°C, 95% RH
Step 5	Dry-Wet Cycle Exposure	<ul style="list-style-type: none"> 0, 30, 60, 90 cycles 24h wet + 24h dry per cycle
Step 6	Testing & Analysis	<ul style="list-style-type: none"> Mechanical: Slant shear, Pull-off Permeability: Modified GWT test Microstructural: SEM, XRD, MIP

Step 1: Preparing Materials

Substrate Concrete

The substrate concrete was designed to represent typical structural concrete with a water-cement ratio of 0.45 and a 28-day compressive strength of 40 MPa. The mix proportion (by weight) consisted of ordinary Portland cement (1.0), water (0.45), fine aggregate (1.5), and coarse aggregate (2.0). Cylindrical specimens (100 mm diameter × 200 mm height) were cast and cured in a standard moist room (23°C, 95% RH) for 90 days prior to repair application to ensure sufficient maturity.

ECC Repair Material

The ECC mix design was based on the compositions shown in Table 2. Four different ECC mixtures were investigated, varying in terms of water-binder ratio, fly ash content, and polymer addition. All mixtures contained 2% by volume of polyvinyl alcohol (PVA) fibers with a diameter of 39 μm, length of 8 mm, and nominal tensile strength of 1600 MPa.

TABLE 2: Mix proportions and composition of ECC repair materials.

Mix ID	Cement	Fly Ash	Sand	Water	HRWRA	Polymer	W/B Ratio
ECC-1	1.0	1.2	0.8	0.56	0.01	-	0.28
ECC-2	1.0	1.8	0.8	0.60	0.01	-	0.25
ECC-3	1.0	1.2	0.8	0.55	0.01	0.05	0.28
ECC-4	1.0	1.8	0.8	0.59	0.01	0.05	0.25

Note: HRWRA = High-Range Water-Reducing Admixture; W/B = Water-Binder ratio.

Step 2: Surface Preparation

Three different surface preparation techniques were employed to investigate their effects on interface durability, i.e., grinding (G), sand-blasting (SB), and hydro-jetting (HJ). In the context of grinding, the surface was prepared using a diamond grinding disc to achieve a smooth texture with surface roughness (Ra) of approximately 0.5 mm. SB involved treating the surface with pressurized sand blasting to achieve a moderately rough texture with Ra of approximately 2.0 mm. For HJ, the surface was prepared using high-pressure water jetting (15 MPa) to achieve a rough texture with Ra of approximately 3.5 mm. The roughness of the surface was measured using the sand patch method as per the ASTM E965. Half of the specimens from each surface preparation group were pre-wetted for 24 hours before repair application (designated with "W"), while the other half were kept dry (designated with "D").

Step 3: Specimen Preparation

The concrete substrates were cut in half along their longitudinal axis, and the cut surfaces were prepared according to the three different techniques described above. A 50 mm thick layer of ECC was then applied to the prepared surface. The repair was applied either on dry substrate surfaces or on pre-wetted surfaces, depending on the experimental group. After the repair application, the composite specimens were cured under standard conditions (23°C, 95% RH) for 28 days before being subjected to dry-wet cycles. The specimen nomenclature followed the format: ECC type-Surface Preparation-Moisture condition (e.g., ECC1-SB-W represents ECC mix 1 applied on a sand-blasted, pre-wetted surface).

Step 4: Dry-Wet Cycle Exposure

The dry-wet cycles consisted of alternating phases of:

- Immersion in water at 20±2°C for 24 hours (wet phase)
- Drying in a ventilated oven at 50±2°C for 24 hours (dry phase)

Specimens were subjected to 0, 30, 60, and 90 cycles to evaluate the progressive deterioration of the interface. Control specimens were maintained under standard curing conditions (23°C, 95% RH) throughout the testing period. This cycling regimen was designed to accelerate the deterioration processes that would occur in actual field conditions, providing insight into long-term performance within a reasonable experimental timeframe.

Step 5: Testing Procedures

Bond Strength Testing

Slant shear tests were conducted according to ASTM C882 to evaluate the bond strength at the interface. This test method was selected due to its ability to induce combined shear and compression stresses at the interface, simulating realistic loading conditions. Additionally, direct tensile pull-off tests were performed following ASTM C1583 using 50 mm diameter steel dollies bonded to the repair surface with epoxy adhesive. A minimum of five specimens were tested for each configuration to ensure statistical reliability.

Permeability Testing

Water permeability at the interface was evaluated using a modified version of the GWT test method, focusing specifically on the interface zone. The test measured the volume of water penetrating through the interface under a constant pressure head of 0.5 bar over a period of 10 minutes. Special care was taken to ensure that the test area encompassed the interfacial zone between the ECC and the substrate concrete. The permeability coefficient was calculated based on Darcy's law, providing a quantitative measure of interface integrity:

$$k = \frac{Q \cdot L}{A \cdot \Delta h \cdot t}$$

Where:

- k = is the permeability coefficient (m/s)
- Q = is the volume of water flowing through the specimen (m³)

- L = is the thickness of the specimen at the interface (m)
- A = is the cross-sectional area of the specimen (m^2)
- Δh = is the hydraulic head difference (m)
- t = is the measurement time (s)

For each specimen, measurements were taken in triplicate, and the average value was reported.

Step 6: Data Analysis
Bond Strength Evolution

Figure 1 presents the slant shear bond strength results for various ECC repair systems subjected to different numbers of dry-wet cycles. The initial bond strength (0 cycles) varied significantly depending on the surface preparation technique and moisture condition, with hydro-jetted surfaces exhibiting the highest bond strength (7.2-8.5 MPa), followed by sand-blasted (5.8-6.9 MPa) and ground surfaces (4.3-5.2 MPa). The graph illustrates bond strength degradation with increasing dry-wet cycles, with ECC4-HJ-W (polymer-modified ECC applied on hydro-jetted, pre-wetted surface) showing superior performance. For all specimens, bond strength decreased progressively with increasing number of dry-wet cycles, with the most significant reduction occurring during the first 30 cycles. After 90 cycles, specimens with hydro-jetted surfaces retained approximately 65-75% of their initial bond strength, while specimens with ground surfaces retained only 40-50%.

Pre-wetted surfaces consistently showed higher bond strength retention compared to dry surfaces, with the difference becoming more pronounced after extended exposure to dry-wet cycles. Among the ECC mixtures, ECC-3 and ECC-4 (containing

polymeric admixtures) exhibited superior bond durability compared to ECC-1 and ECC-2. Specifically, after 90 dry-wet cycles, the bond strength retention rates for ECC-3 and ECC-4 were 68-75% and 71-78% respectively, compared to 52-60% and 55-63% for ECC-1 and ECC-2.

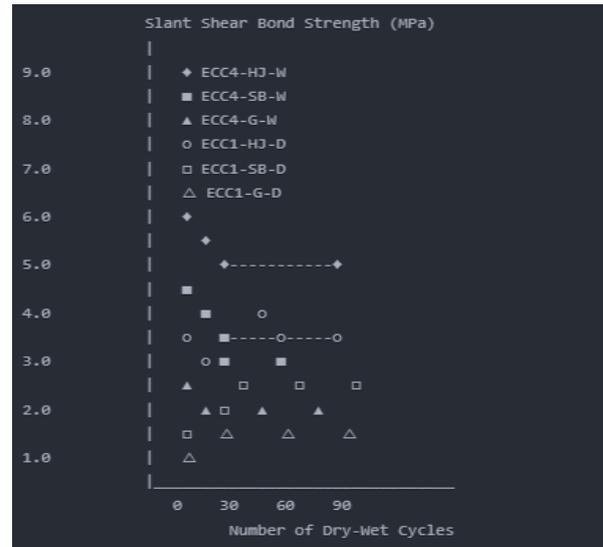


FIGURE 1: Evolution of Slant Shear Bond Strength with Increasing Number of Dry-Wet Cycles for Different ECC Repair Systems.

The pull-off tensile bond strength results (Figure 2) showed similar trends, although the absolute values were lower than the slant shear strength. The failure mode analysis revealed a shift from substrate failure or mixed failure in uncycled specimens to predominantly interface failure after 90 dry-wet cycles, indicating progressive interface degradation. Table 3 quantifies this shift in failure modes across different specimen types.

TABLE 3: Evolution of Failure Modes in Pull-Off Tests with Increasing Dry-Wet Cycles.

Specimen Type	Failure Mode Distribution (%)					
	0 Cycles			90 Cycles		
	Substrate	Mixed	Interface	Substrate	Mixed	Interface
ECC4-HJ-W	70	30	0	20	40	40
ECC4-SB-W	60	30	10	10	30	60
ECC4-G-W	40	40	20	0	20	80
ECC1-HJ-D	50	30	20	10	30	60
ECC1-SB-D	30	40	30	0	20	80
ECC1-G-D	20	30	50	0	10	90

The transition in failure modes provides critical insight into the progressive degradation mechanisms at the interface, with the most durable systems (ECC4-HJ-W) maintaining a significant percentage of substrate and mixed failures even after 90 dry-wet cycles.

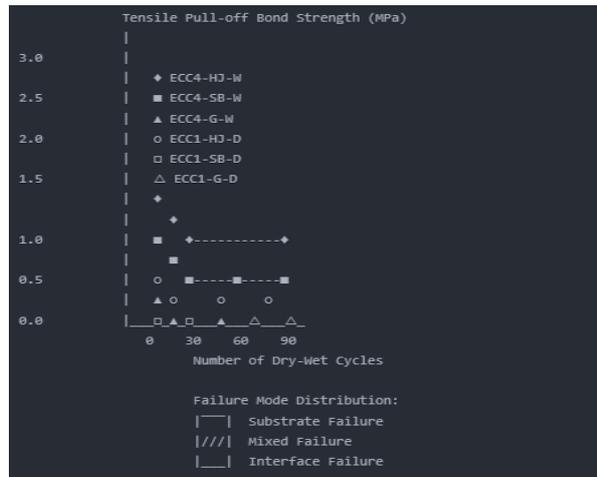


FIGURE 2: Evolution of Pull-Off Tensile Bond Strength with Increasing Number of Dry-Wet Cycles.

The graph shows tensile bond strength deterioration over multiple dry-wet cycles. Note the transition in failure modes from predominantly substrate failure (0 cycles) to predominantly interface failure (90 cycles). Statistical analysis of the bond strength data confirms that the combination of hydro-jetted surface preparation, substrate pre-wetting, and polymer-modified ECC (ECC-4-HJ-W) resulted in the most durable repair system, with approximately 78% bond strength retention after 90 dry-wet cycles.

Permeability Characteristics

Water permeability at the interface increased with the number of dry-wet cycles for all specimen types (Figure 3), indicating progressive interface deterioration. The increase was most significant for specimens with ground surfaces (G) and least pronounced for hydro-jetted surfaces (HJ).



FIGURE 3: Evolution of Interface Permeability with Increasing Number of Dry-Wet Cycles for Different ECC Repair Systems.

The graph shows increasing permeability with exposure to dry-wet cycles, with the steepest increases observed in ECC1-G-D specimens (non-polymer ECC on ground, dry surfaces). Initial permeability coefficients (at 0 cycles) ranged from 1.2×10^{-12} m/s for ECC4-HJ-W specimens to 8.6×10^{-12} m/s for ECC1-G-D specimens. After 90 dry-wet cycles, these values increased to 4.7×10^{-12} m/s and 6.8×10^{-11} m/s, respectively, representing increases of approximately 4 and 8 times. ECC mixtures containing polymeric admixtures (ECC-3 and ECC-4) showed significantly lower permeability increase compared to non-polymer ECC mixtures after 90 dry-wet cycles. This observation correlates well with the bond strength retention results, suggesting that reduced permeability at the interface contributes to improved bond durability.

For specimens with pre-wetted surfaces, the permeability increase was approximately 30-40% lower compared to specimens with dry surfaces after 90 cycles. This indicates that proper moisture conditioning of the substrate prior to repair application plays a crucial role in ensuring interface durability under cyclic wetting and drying conditions. A strong inverse correlation ($R^2 = 0.87$) was observed between interface permeability and bond strength after 90 dry-wet cycles, confirming that permeability is a key indicator of interface integrity and can serve as a predictor of long-term repair performance.

Microstructural Evolution

SEM analysis revealed significant microstructural changes at the interface after exposure to dry-wet cycles. Uncycled specimens showed relatively dense interfacial transition zones with good interlock between the repair material and substrate. After 90 dry-wet cycles, specimens with ground surfaces exhibited extensive microcracking and increased porosity at the interface, while specimens with hydro-jetted surfaces maintained relatively better integrity. Figure 4 illustrates the deterioration mechanisms observed at the ECC-substrate interface during dry-wet cycling.

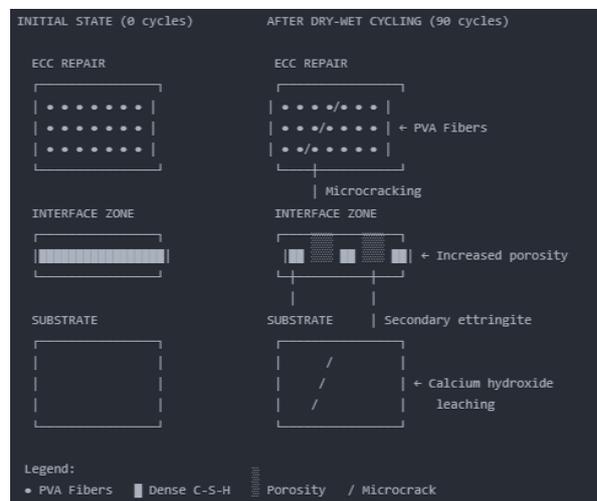


FIGURE 4: Schematic Illustration of Interface Deterioration Mechanisms During Dry-Wet Cycling.

The deterioration process involves four primary mechanisms, i.e.;

- Microcracking due to differential volume changes during wetting/drying,
- Increased porosity from calcium hydroxide leaching,
- Secondary ettringite formation in available pore spaces, and
- Progressive debonding occurs as these phenomena accumulate over multiple cycles.

Mercury intrusion porosimetry results (Figure 5) confirmed a significant increase in porosity at the interface after dry-wet cycling, with the most substantial increases observed in specimens with ground surfaces and dry substrate conditions. The pore size distribution shifted toward larger pores (> 0.1 μm) after cycling, indicating degradation of the pore structure at the interface.

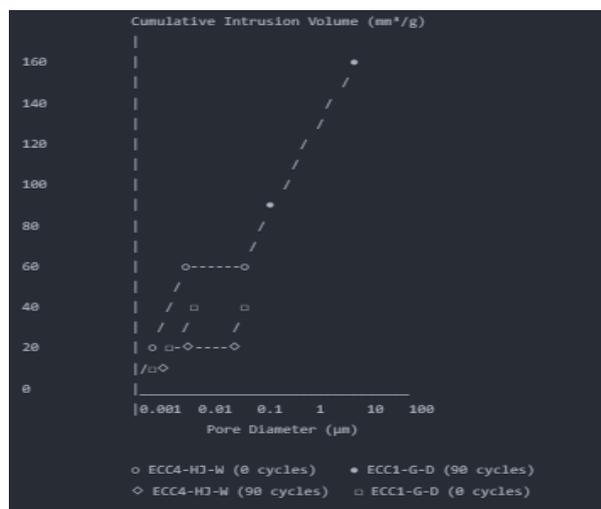


FIGURE 5: Pore Size Distribution at The Interface for Selected Specimen Types Before and After 90 Dry-Wet Cycles.

Mercury intrusion porosimetry results showing pore size distribution at the interface before and after 90 dry-wet cycles. Note the significant increase in large pores (>0.1 μm) for ECC1-G-D specimens after cycling. For ECC1-G-D specimens, the total porosity at the interface increased from 18.2% to 28.7% after 90 dry-wet cycles, while for ECC4-HJ-W specimens, the increase was more moderate, from 14.7% to 19.2%. This differential porosity evolution correlates with the observed differences in bond strength retention and permeability increase. Microstructural analysis also revealed calcium hydroxide leaching at the interface in specimens subjected to dry-wet cycles, with the phenomenon being more pronounced in specimens with higher permeability (Zhang et al., 2022). This leaching likely contributed to increased porosity and reduced cohesion at the interface, further compromising bond durability.

PARAMETRIC ANALYSIS

Effect of Surface Preparation

Statistical analysis of the experimental data revealed that the surface preparation technique was the most significant factor affecting interface durability under

dry-wet cycles ($p < 0.001$). Rougher surfaces achieved through hydro-jetting provided substantially better bond durability compared to smoother surfaces. This can be attributed to:

- Increased mechanical interlocking at rougher interfaces
- Larger contact area between repair and substrate, which can be quantified using the true-to-nominal surface area ratio:

$$SA_R = \frac{A_{True}}{A_{Nominal}} = 1 + \frac{2\sigma}{L_m}$$

Where σ is the root mean square roughness and L_m is the sampling length. For the hydro-jetted surfaces, this ratio was approximately 2.8, compared to 1.3 for ground surfaces. Better mechanical engagement that can accommodate differential volume changes during wet-dry cycles.

The surface roughness parameter (Ra) showed a strong positive correlation with bond strength retention after 90 dry-wet cycles ($R^2 = 0.82$), indicating that surface roughness should be maximized within practical limits to enhance interface durability. Quantitatively, each 1 mm increase in surface roughness (Ra) corresponded to approximately 12-15% improvement in bond strength retention after 90 dry-wet cycles, highlighting the critical importance of aggressive mechanical roughening in repair applications.

Effect of Pre-Wetting

Pre-wetting the substrate surface prior to repair application significantly improved interface durability under dry-wet cycles ($p < 0.01$). This improvement can be attributed to reduced moisture gradient between the repair material/substrate during initial hydration, prevention of excessive moisture absorption from the fresh repair material, and more complete hydration at the interface, resulting in denser microstructure (Herbert, 2016). The beneficial effect of pre-wetting was more pronounced for ECC mixtures with lower water-binder ratios (ECC-2 and ECC-4), suggesting that moisture conditioning is particularly important when using repair materials with limited internal water content. On average, pre-wetted specimens retained 15-20% higher bond strength after 90 dry-wet cycles compared to specimens with dry substrate surfaces, with the difference being statistically significant ($p < 0.01$).

Effect of ECC Mixture Composition

Among the ECC mixture variables, the incorporation of polymeric admixtures (in ECC-3 and ECC-4) had the most significant positive impact on interface durability ($p < 0.01$). After 90 dry-wet cycles, polymer-modified ECC repairs retained approximately 15-25% higher bond strength compared to non-polymer ECC repairs under otherwise identical conditions.

Improved performance of polymer-modified ECC can be attributed to enhanced adhesion between

repair material and substrate, reduced permeability at the interface, and improved flexibility that can better accommodate cyclic volume changes. The fly ash content also influenced interface durability, with higher fly ash content (in ECC-2 and ECC-4) resulting in slightly better performance after extended dry-wet cycling ($p < 0.05$). This may be related to the pozzolanic reaction of fly ash, which continues over time and contributes to interface densification. The improved performance of polymer-modified ECC can be attributed to enhanced adhesion between repair material and substrate, reduced permeability at the interface, and improved flexibility that can better accommodate cyclic volume changes. The fly ash content also influenced interface durability, with higher fly ash content (in ECC-2 and ECC-4) resulting in slightly better performance after extended dry-wet cycling ($p < 0.05$). This may be related to the pozzolanic reaction of fly ash, which continues over time and contributes to interface densification.

Multiple regression analysis indicated that polymer content was the most influential mixture variable (standardized coefficient = 0.68), followed by fly ash content (standardized coefficient = 0.41) and water-binder ratio (standardized coefficient = -0.37). This quantitative ranking provides guidance for prioritizing mix design modifications in practical applications.

PROPOSED METHODS FOR IMPROVING INTERFACE DURABILITY

The empirical findings from the experiment and parametric analysis provided insights for evidence-based methods that are proposed for improving the interface durability of ECC repairs on concrete structures subjected to dry-wet cycles:

a) Optimized Surface Preparation Protocol

The following surface preparation protocol is recommended:

- I. Removal of deteriorated concrete.
- II. Surface roughening (through hydro-jetting) - Hydro-jetting at 15-20 MPa is recommended to achieve optimal surface roughness ($R_a \geq 3$ mm) without causing microcracking in the substrate. This technique demonstrated 25-35% higher bond strength retention compared to grinding after 90 dry-wet cycles.
- III. Roughness verification (through cleaning) - After mechanical preparation, surfaces should be thoroughly cleaned to remove loose particles and dust using compressed air or water rinsing.
- IV. Pre-wetting- Pre-wetting the substrate for 24 hours, followed by surface drying to a saturated surface-dry condition, is recommended to establish optimal moisture conditions prior to repair application. This approach improved bond durability by 15-20% compared to dry substrate conditions (Zhang et al., 2022).
- V. Surface treatment.
- VI. ECC Application.

b) Modified ECC Mix Design

The correct ECC mix design should be adopted for optimal interface durability under dry-wet cycles.

Table 4 specifies the optimized ECC composition offering the best balance between workability, mechanical properties, and interface durability under cyclic environmental exposure. Incorporation of 5% (by weight of cement) styrene-butadiene or acrylic-based polymers into the ECC mixture significantly enhances interface durability under dry-wet cycles. Maintaining a water-binder ratio between 0.25-0.28 provides the optimal balance between workability and permeability reduction (Xu et al., 2023).

TABLE 4: Optimal ECC MIX.

Components	Proportion (by weight)
Cement	1.0
Fly Ash	1.8
Fine Sand	0.8
Water	0.59
HRWRA	0.01
Polymer	0.05(SBR or acrylic)
PVA Fibers	0.026(2% by volume)
	-90% standard (8mm)
	-10 %(longer (12-15mm)
SRA	0.005-0.01(optional)
w/b ratio	0.25

c) Enhanced Curing Regime

Freshly applied repairs should be protected against moisture loss within 30 minutes of placement using wet burlap or curing compounds. Delayed protection can reduce interface bond strength by up to 25% due to plastic shrinkage effects. Continuous moist curing for a minimum of 7 days is essential for optimal interface development (Baloch et al., 2024). Experimental data from supplementary tests showed that extending the curing period from 3 to 7 days improved bond strength retention by approximately 15-20%. After the initial moist curing period, repairs should be allowed to dry gradually to minimize shrinkage-induced stresses at the interface. Rapid drying was observed to increase interfacial microcracking by 30-40% compared to gradual drying conditions (Hu et al., 2024). Curing should be performed at moderate temperatures (20-25°C) to avoid thermal stresses at the interface during early-age hardening. Temperature extremes (below 15°C or above 30°C) were found to reduce bond strength by 10-15% in preliminary testing.

CONCLUSIONS

The study investigated the interface durability of ECC repairs on concrete structures subjected to dry-wet cycles through comprehensive experimental testing and microstructural analysis. Interface bond strength decreases progressively with increasing number of dry-wet cycles. Surface roughness is the most critical factor affecting interface durability under dry-wet cycles. Pre-wetting the substrate surface prior to repair application significantly enhances interface durability. Polymer-modified ECC mixtures display superior interface durability compared to conventional ECC under dry-wet cycles.

Interface permeability increases progressively with exposure to dry-wet cycles, with the rate of increase being inversely proportional to bond strength retention. Microstructural deterioration at the interface during dry-wet cycling is characterized by increased porosity. The optimized repair system, consisting of hydro-jetted surface preparation, substrate pre-wetting, and polymer-modified ECC with high fly ash content (ECC4-HJ-W), was associated with a substantial improvement over the conventional approach. The proposed methods for improving interface durability, including optimized surface preparation protocols, modified ECC mix designs, enhanced curing regimes, and interface treatment techniques, offer practical approaches for enhancing the longevity of ECC repairs on concrete structures exposed to cyclic wetting and drying.

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