



Performance Evaluation of PVA Fiber-Reinforced Concrete

Roof Slabs under Hot-Humid Climate Conditions

Tianzhu Song¹, Chaiporn Supahitanukool^{1*}, Phanupong Samol¹ and Winai Ouyornprasert²

Faculty of Engineering and Technology, Pathumthani University¹

Faculty of Engineering and Technology, Pathumthani University^{1*}

College of Engineering, Rangsit University²

Corresponding author's e-mail: chaiporn.s@ptu.ac.th



Abstract

Concrete roof slabs in hot-humid climates are highly susceptible to shrinkage cracking and durability deterioration under coupled temperature-humidity cycling. Polyvinyl alcohol (PVA) fiber is recognized for its crack-bridging capability and cementitious bond strength, yet the optimal dosage for roof slabs exposed to such conditions remains insufficiently defined. This study experimentally evaluated PVA fiber-reinforced C30 concrete at five volume fractions (0.00–0.50%) through compressive and flexural strength testing, water absorption measurement, and accelerated temperature-humidity cycling (30 cycles). At 0.10% fiber content, compressive strength increased by 3.4%, flexural strength by 20.5%, and water absorption decreased by 11.5% relative to plain concrete. After cycling, crack width and mass loss were reduced by 69% and 65%, respectively. Excessive dosage (0.50%) caused fiber agglomeration and performance decline. A fiber content of 0.10% by volume demonstrated the optimal balance of strength, durability, crack control, and constructability. These findings provide practical guidance for designing durable roof slab concrete in hot-humid climates and support the broader application of fiber-reinforced concrete in climate-adaptive construction.

Keywords: PVA fiber concrete; roof slabs; hot-humid climate; durability; fiber dosage optimization

Introduction

Concrete roof slabs in hot-humid climates are continuously exposed to high temperature, elevated humidity, intense solar radiation, and seasonal rainfall. These coupled temperature-humidity cycles accelerate drying shrinkage, induce thermal stresses, and promote microcracking, leading to increased permeability and durability deterioration (Ding et al., 2022; Zhang et al., 2022). Improving crack resistance and durability of roof slab concrete under such conditions is therefore a critical engineering challenge. Polyvinyl alcohol (PVA) fiber-reinforced concrete offers superior crack-bridging capability and strong interfacial bonding with the cement matrix, enhancing toughness and durability (Chen et al., 2021; Jiang et al., 2021). However, most existing studies have focused on beam elements or mortar specimens under laboratory-controlled conditions, with limited attention to roof slab applications subjected to coupled temperature-humidity cycling (Liu et al., 2022; Nguyen et al., 2024). Moreover, the optimal fiber dosage balancing mechanical performance, durability, and workability remains insufficiently defined (Wang et al., 2023; Zhou et al., 2024). This study experimentally evaluates PVA fiber-reinforced C30 concrete for roof slab applications in hot-humid climates, with objectives to: (1) assess compressive and flexural strength; (2) investigate crack resistance and water absorption; and (3) evaluate durability under accelerated temperature-humidity cycling. The aim is to identify the optimal fiber dosage providing balanced improvement in strength, durability, crack control, and constructability for climate-adaptive roof slab design.

Materials and Methods

- Materials and Mix Design** C30 concrete was prepared using Ordinary Portland Cement (P-O 42.5), crushed stone (5–10 mm), medium sand (FM ≈ 2.6), and potable water at a fixed water-cement ratio of 0.45. The base mix comprised cement 380, water 171, sand 720, and gravel 1,100 kg/m³. PVA fibers (12 mm length) were incorporated at five volume fractions: 0.00%, 0.05%, 0.10%, 0.20%, and 0.50% (corresponding to 0, 0.65, 1.30, 2.60, and 6.50 kg/m³), with all other proportions held constant.
- Specimen Preparation** Cube specimens (150 mm) and prisms were cast using a forced mixer to ensure uniform fiber dispersion. Each dosage group comprised 18 specimens allocated for compressive, flexural, water absorption, and durability tests. All specimens were cured at 20 ± 2 °C and RH ≥ 95% for 28 days prior to testing.
- Testing Program** Compressive and flexural tensile strengths were measured in accordance with GB/T 50081-2019. Water absorption was determined by oven-drying specimens at 105 °C to constant mass, followed by 48-hour water immersion, and calculated as $WA (\%) = (M_{sat} - M_{dry}) / M_{dry} \times 100$. For durability evaluation, specimens underwent 30 accelerated temperature-humidity cycles alternating between 35 °C / 85% RH (daytime simulation) and 25 °C / 55% RH (night/rain simulation), producing ΔRH ≥ 30% to reproduce environmental stresses on roof slabs. Crack width, crack distribution, mass loss, and surface deterioration were assessed after cycling.
- Data Analysis** Results were expressed as mean values of at least three replicates with standard deviations. Performance was compared across fiber dosages as improvement percentages relative to plain concrete. Statistical significance was evaluated at a 95% confidence level. All procedures complied with GB/T 50081-2019 and GB/T 50082-2009.

Result

- Compressive Strength** PVA fiber incorporation exhibited a dosage-dependent effect on 28-day compressive strength (Fig. 1). Maximum strength of 39.5 MPa was achieved at 0.10% fiber content (+3.4% over plain concrete, 38.2 MPa), while 0.20% yielded 38.9 MPa (+1.8%). At 0.50%, strength declined to 36.4 MPa (-4.7%) due to fiber agglomeration and increased void content.
- Flexural Tensile Strength** PVA fibers significantly enhanced flexural performance through crack-bridging action (Fig. 2). At 0.10%, flexural strength reached 5.12 MPa (+20.5% over 4.25 MPa for plain concrete). The 0.20% dosage achieved the highest value of 5.28 MPa (+24.2%), while 0.50% yielded 4.86 MPa (+14.4%). The marginal gain from 0.10% to 0.20% was only 0.16 MPa (+3.1%), indicating diminishing returns.
- Water Absorption** Fiber incorporation progressively reduced capillary porosity and permeability (Fig. 3). Minimum absorption of 4.38% (-14.5% relative to plain concrete, 5.12%) was recorded at 0.20%. At 0.10%, absorption was 4.53% (-11.5%). At 0.50%, absorption increased slightly to 4.72%, likely due to additional interfacial porosity from fiber agglomeration.

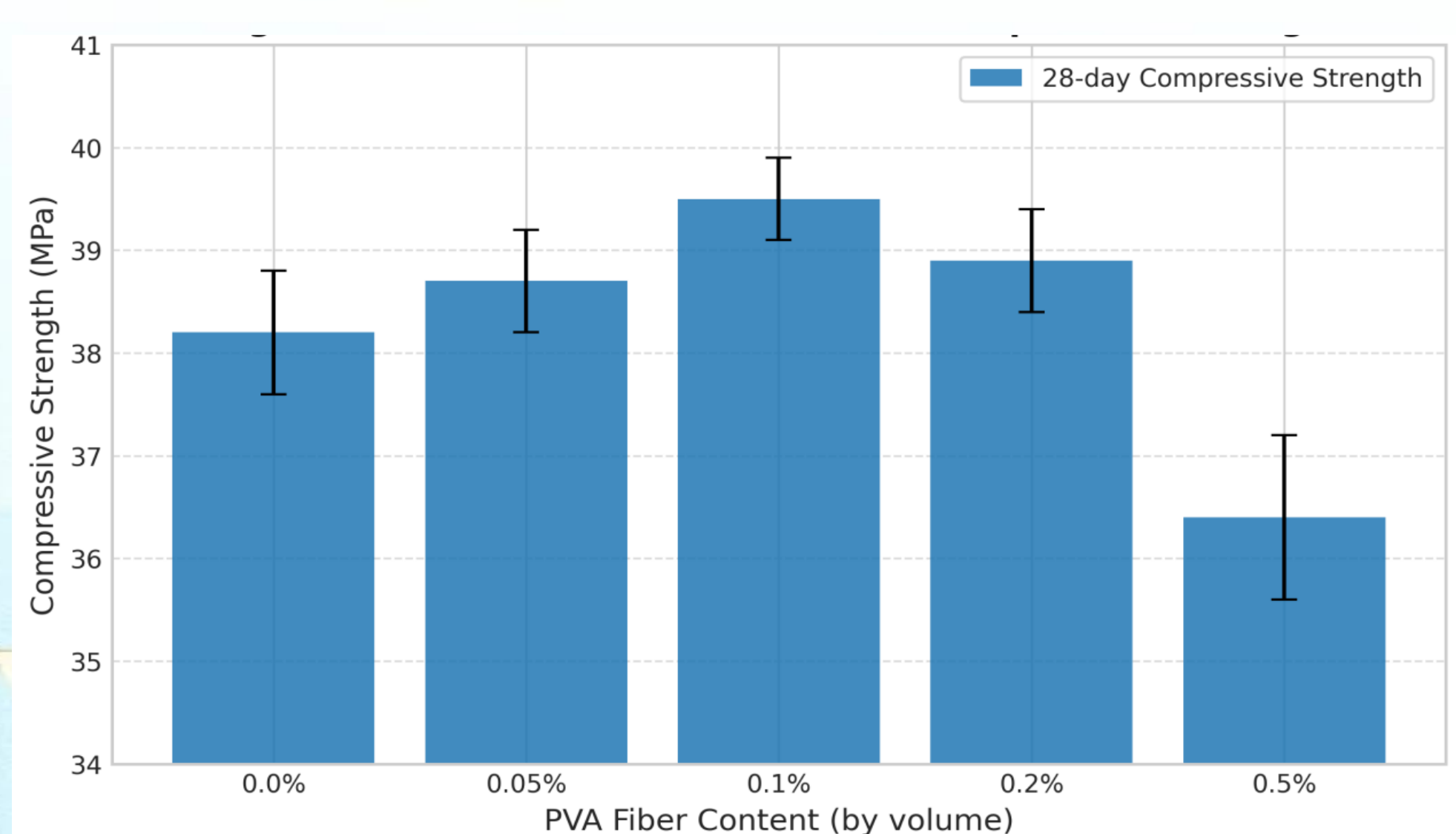


Figure 1 Effect of Fiber-Content on 28-Day Compressive Strength

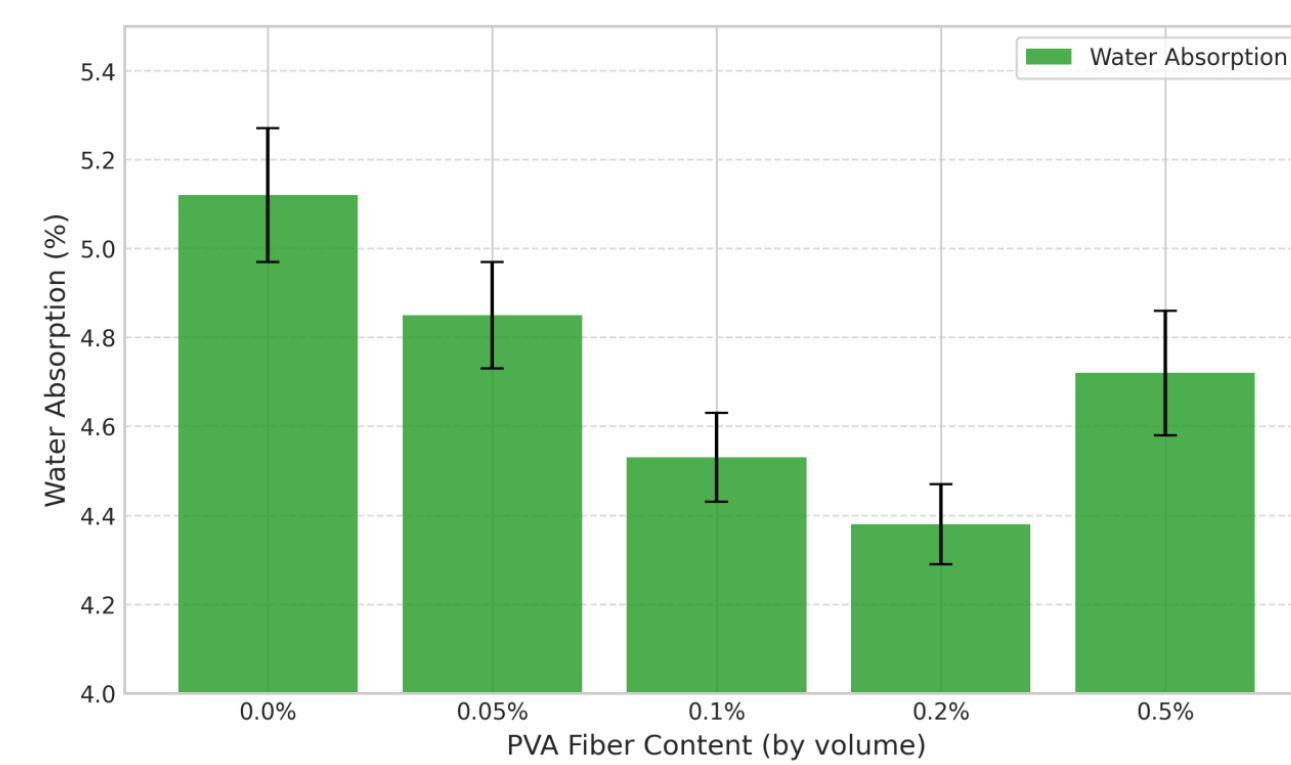


Figure 2 Effect of Fiber Content on 28-Day Flexural Strength

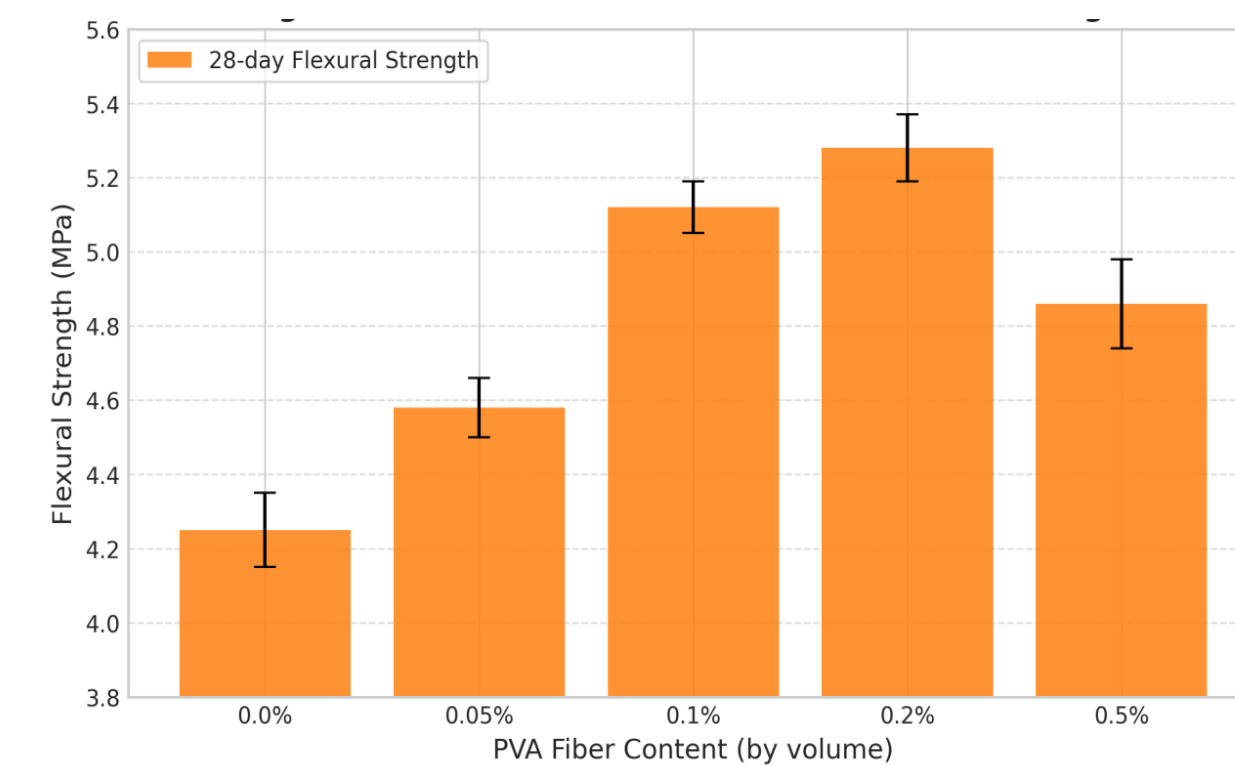


Figure 3 Effect of Fiber Content on Water Absorption

- Accelerated Durability Performance** After 30 temperature-humidity cycles, fiber-reinforced specimens demonstrated significantly improved crack resistance. At 0.10% fiber content, average crack width was reduced to 0.08 mm (-69% from 0.26 mm) and total crack length decreased by 80% (Fig. 4). The 0.20% dosage achieved the smallest crack width of 0.05 mm (-81%) with 87% crack length reduction. Mass loss (Fig. 5) decreased from 1.18% for plain concrete to 0.41% at 0.10% (-65%) and 0.28% at 0.20% (-76%). The incremental gains from 0.10% to 0.20% were modest: only 0.03 mm in crack width and 0.13 percentage points in mass loss.

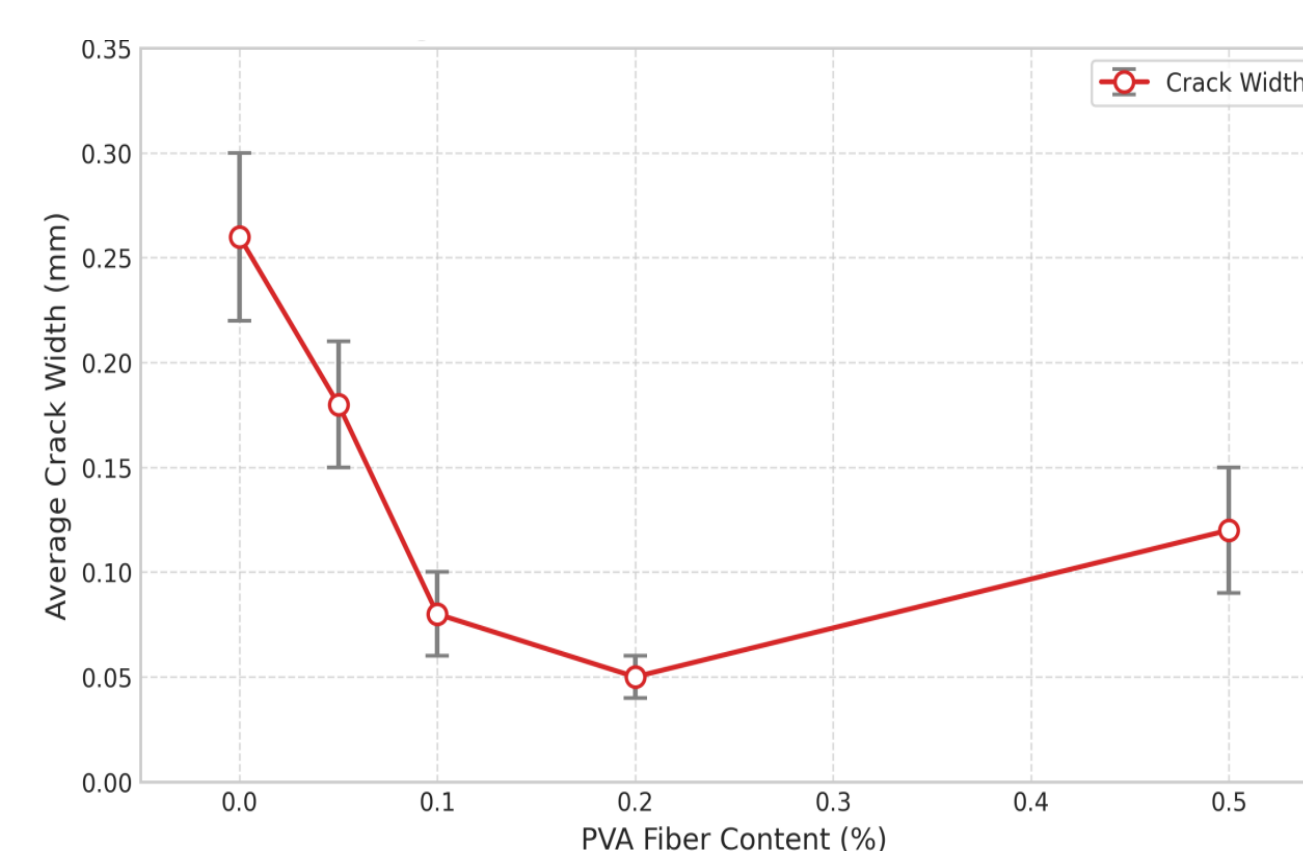


Figure 4 Effect of Fiber Content on Crack Width after Humidity Cycling

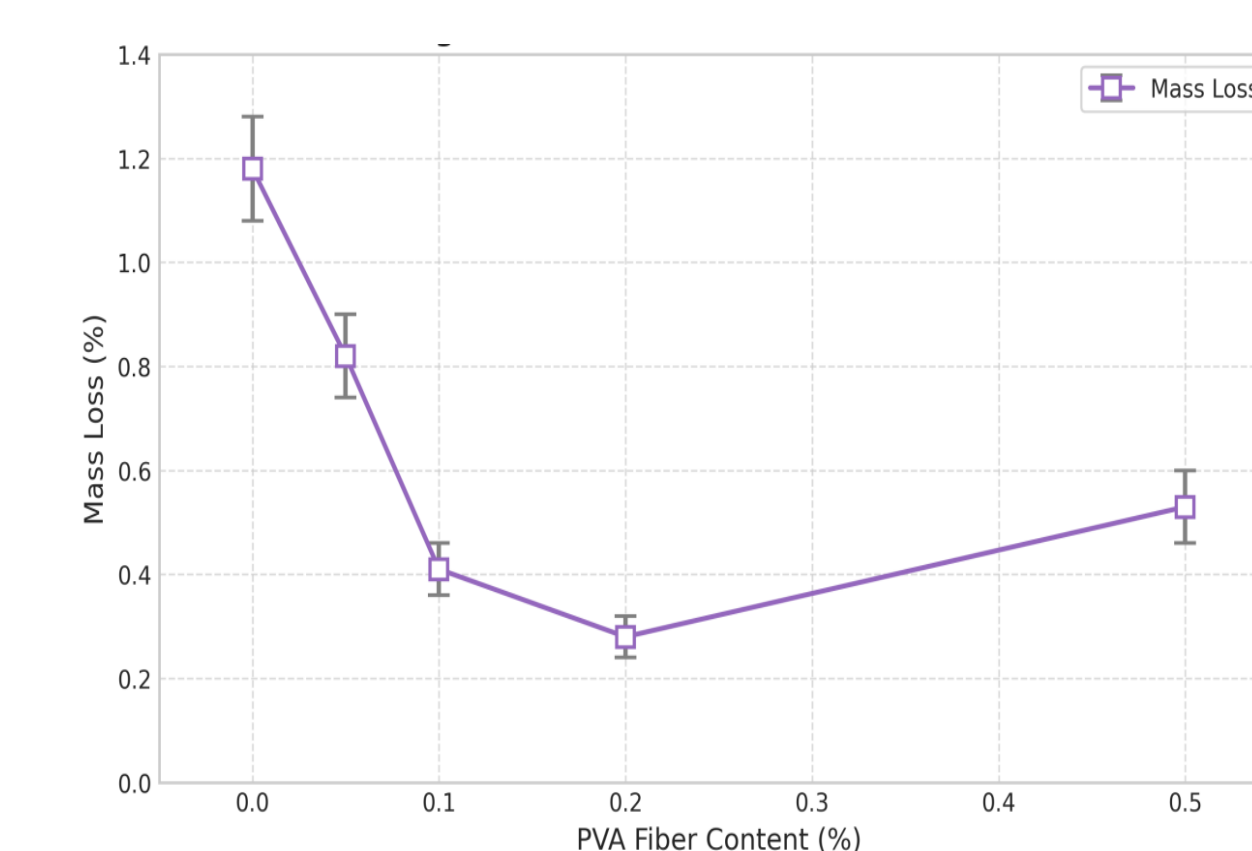


Figure 5 Effect of Fiber Content on Mass Loss after Humidity Cycling

- Overall Performance Evaluation** Across all indicators, 0.10% PVA fiber by volume provided the most balanced performance: +3.4% compressive strength, +20.5% flexural strength, -11.5% water absorption, -69% crack width, and -65% mass loss under humidity cycling conditions.

Conclusions

- Compressive strength was maximized at 0.10% PVA fiber content (39.5 MPa, +3.4%), with decline observed at 0.50% due to fiber agglomeration. The future development of renewable energy technology derived from wastewater. (Sinagra et al., 2022)
- Flexural strength peaked at 0.20% (5.28 MPa, +24.2%), though the gain from 0.10% to 0.20% was only 0.16 MPa (+3.1%), indicating diminishing returns.
- Water absorption decreased up to 0.20% (minimum 4.38%, -14.5%), with 0.10% achieving 4.53% (-11.5%).
- Durability under humidity cycling was substantially enhanced: at 0.10%, crack width and mass loss were reduced by 69% and 65%, respectively, with only marginal further improvement at 0.20%.
- Considering strength, durability, cost, and workability collectively, 0.10% PVA fiber by volume is recommended as the optimal dosage for roof slab concrete in hot-humid climates.

Recommendations and Future Work

For practical application, a PVA fiber dosage of 0.10% by volume (≈1.30 kg/m³) is recommended for roof slab concrete in hot-humid climates, providing balanced crack resistance, durability, and mechanical performance with acceptable workability. Future research should focus on long-term field performance validation, full-scale structural testing, and mix design optimization (e.g., water-cement ratio adjustment and superplasticizer incorporation) to enhance fiber dispersion and confirm practical applicability under real engineering conditions.

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