Beyond Habakkuk: Investigating Pykrete in the 21st Century

LITERATURE REVIEW

Pykrete, a sawdust-ice composite named after Geoffrey Pyke, was developed during WWII for aircraft carrier construction. Traditionally composed of 14% wood fibre and 86% water, it demonstrated remarkable strength when it resisted axe splitting and ricocheted bullets during military demonstrations.

Recent studies suggest optimal sawdust concentrations ranging from 2% to 18%. Hani and Evirgen (2022) found 18% sawdust at -20°C achieved 4.83 MPa compressive strength. Vasiliev (2015) reported 10% sawdust provided optimal results (12 MPa, 3× stronger than ice). However, a critical gap exists: most studies focus solely on compressive strength without considering workability and mouldability for practical construction.

OBJECTIVE

Research Question

How does the composition of pykrete affect the failure of the sawdust-ice composite under compressive load and its workability?

Hypotheses

H_0: Wood fibre composition >10% by weight will produce no change in pykrete compressive strength and workability.

H_a: Wood fibre compositions >10% will produce pykrete with superior compressive strength and workability.

METHODOLOGY

Sample Preparation

Pykrete samples with varying sawdust concentrations (0-25% m/v) were prepared by mixing measured masses of sawdust with 2000 mL distilled water. Five 250g samples per concentration were moulded in silicone bread trays and frozen at -20°C for 24 hours to 1 week.

Compressive Testing

A custom wooden compression frame with stackable weight plates applied controlled loads. Failure points were recorded when cracking, fragmentation, or structural collapse occurred. Loads were converted to pressure (KPa) using sample cross-sectional area (207 × 80 mm).

Workability Assessment

Slump tests measured vertical settling distance using a 98mm height plastic cup mould. Fresh mixtures were poured, the mould lifted vertically, and final height measured to determine shape retention.

Compression test apparatus

Slump test with sawdust-water mixture

CONCLUSION

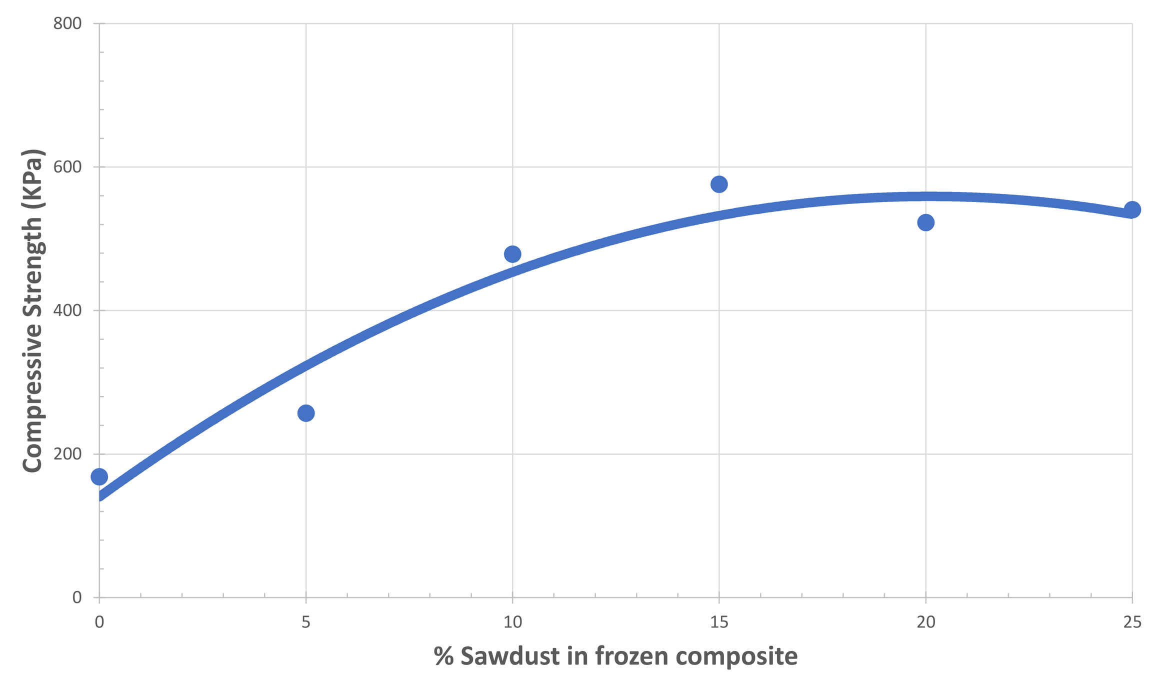
This investigation successfully identified an optimum in pykrete composite performance at 15-20% sawdust concentration, enabling rejection of the null hypothesis. The quadratic relationship (R^2 = 0.94, p = 0.02) demonstrated peak performance at 15% sawdust (576 ± 177 KPa), representing a 242% increase over ice controls.

Workability analysis revealed that concentrations ≥10% sawdust provide excellent mouldability (≤0.2 mm slump), overlapping with the strength optimum. This demonstrates that pykrete can achieve superior mechanical properties without sacrificing practical construction requirements, positioning it as a transformative solution for temporary structures and cold-region construction.

RESULTS

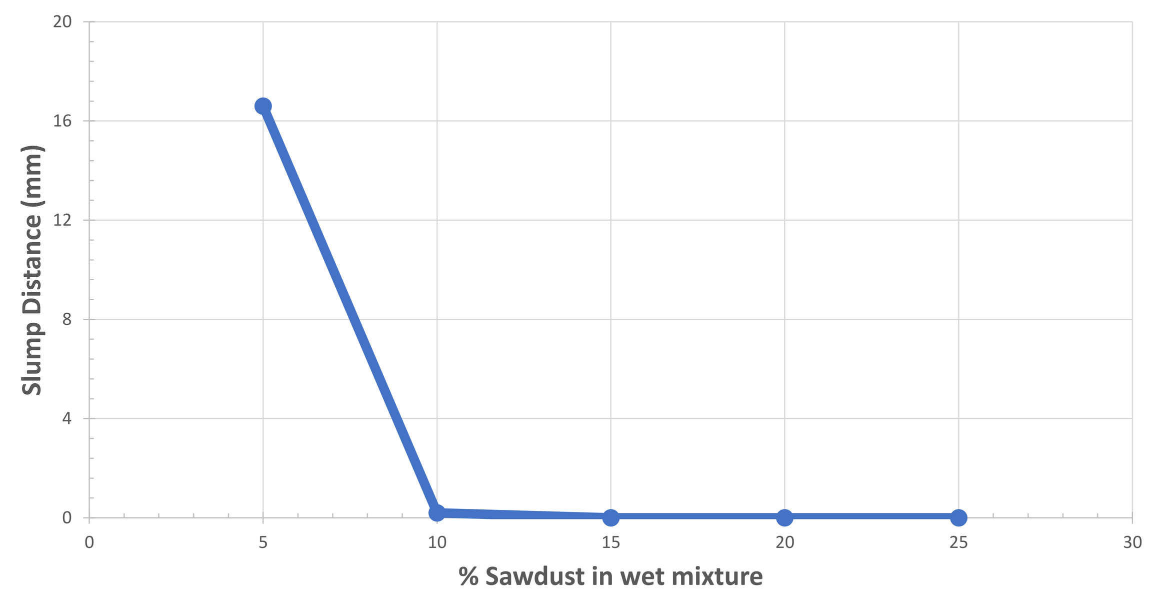
Peak compressive strength at 15% sawdust: 576 ± 177 KPa (242% increase over ice control)

Compressive Strength



Polynomial regression analysis (R^2 = 0.94, F(29) = 22.22, p = 0.02) revealed a statistically significant quadratic relationship. Ice control (0% sawdust) showed 168 ± 43 KPa. Strength peaked at 15% sawdust (576 ± 177 KPa), then declined. The quadratic model suggests the theoretical optimum lies closer to 20%, indicating an ideal range of 15-20% sawdust.

Workability



Slump testing revealed a critical transition at 10% sawdust. At 5% sawdust, mixtures exhibited poor workability (16.6 ± 13.2 mm settling). At ≥10% sawdust, settling dropped to ≤0.2 mm, demonstrating excellent mouldability. This threshold overlaps with the 15-20% strength optimum.

DISCUSSION

This investigation successfully identified an optimal pykrete composition range (15-20% sawdust) that maximises both compressive strength and workability, enabling rejection of the null hypothesis.

The 15-20% optimum aligns with Hani and Evirgen's (2022) 18% finding but extends beyond traditional formulations. The workability threshold at 10% sawdust addresses a critical gap - previous studies focused solely on mechanical properties, but practical construction requires materials that are both strong and mouldable.

Applications include sustainable temporary structures for events, cold-climate construction, and biodegradable building materials. The material's cost-effectiveness and natural decomposition offer environmental advantages. Future research should refine the precise optimum within the 15-20% range and examine effects of wood type and particle size.

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