

STUDY ON INTERNAL CURING OF HIGH PERFORMANCE CONCRETE WITH PARTIAL REPLACEMENT OF FINE AGGREGATE USING VERMICULTURE

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1: ABSTRACT: Shrinkage behavior and durability properties of M50 grade concrete using Vermiculite as a lightweight internal curing agent. The use of internal curing agents can provide a sufficient volume of water by means of light weight aggregate (LWA) to counteract the effects of shrinkage.

Keywords: High Performance Concrete, Internal Curing, Vermiculite, Silica Fume, Compressive Strength, Flexural Strength, Shrinkage, Durability, Acid Attack, Sulphate Attack.

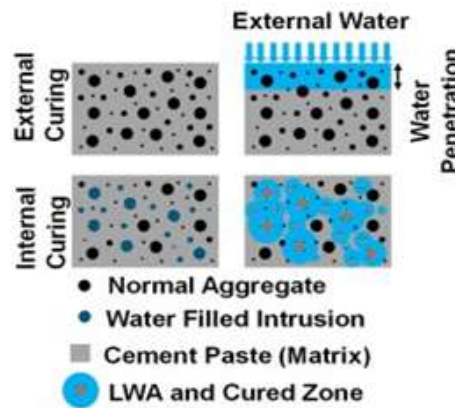
2: INTRODUCTION (GENERAL)

- **Widespread Use:** Concrete is the world's most used construction material due to its moldability, durability, and low cost.
- **Basic Constituents:** It primarily consists of Portland cement, aggregates, water, and admixtures.
- **Cracking Challenges:** Despite its strength, concrete undergoes significant cracking during early ages due to chemical reactions or water loss to the environment.
- **Types of Cracks:** Major forms include plastic shrinkage, settlement, and drying shrinkage cracks.

3: UNDERSTANDING INTERNAL CURING (IC)

- **Definition:** IC involves providing water-filled reservoirs within the concrete that supply water on demand to the hydrating cement paste.
- **Mechanism:** It uses saturated lightweight aggregates (LWA) like vermiculite to replace a portion of fine aggregates.
- **Inside-Out Curing:** Unlike conventional curing which works from the surface in, IC cures the concrete from the inside out.

- **Benefits:** It reduces plastic shrinkage, maintains workability, and ensures moisture equilibrium throughout the concrete mass.



4: HIGH-PERFORMANCE CONCRETE (HPC) CHARACTERISTICS

- **Defining HPC:** Concrete possessing high workability, high strength, and high durability.
- **ACI Standards:** The American Concrete Institute defines high-strength concrete as having a design compressive strength of 6,000 psi (41 MPa) or greater.
- **Key Features:** HPC offers low permeability, no bleeding, a stronger transition zone at the interface, and enhanced long-term performance.

• **Table 1.2 Replacement of fine aggregate**

FA (sand)	LWA (Vermiculite)
100%	-
95%	5%
90%	10%
85%	15%
80%	20%

5: MATERIALS USED - SILICA FUME

- **Source:** Obtained as a byproduct from the production of silicon and ferrosilicon alloys.
- **Role:** Acts as a pozzolanic admixture, reacting with free lime to create more calcium silicate hydrate.
- **Impact:** Enhances mechanical properties, increases density by plugging voids, and protects embedded steel from corrosion.



6: MATERIALS USED - VERMICULITE

- **Nature:** A natural mineral that expands (exfoliates) when heated.
- **Structure:** Features a laminar (layered) crystalline structure that can trap water.
- **Application in Study:** Used as a partial replacement for fine aggregate to provide internal curing moisture.



7: LITERATURE REVIEW (KEY STUDIES I)

- **Hoa Lam (2005):** Investigated LWA's ability to mitigate shrinkage; found that lightweight sand is more effective than lightweight stone for IC.
- **Cusson & Hoogeveen (2006):** Found that replacing 20% of sand with pre-soaked LWA can completely eliminate early-age shrinkage cracking.

8: LITERATURE REVIEW (KEY STUDIES II)

- **Pietro Lura (2008):** Showed that IC reduces self-desiccation; saturated aggregates can actually produce early-age expansion instead of shrinkage.
- **Dale Bentz (2010):** Observed that IC strongly influences the microstructure, leading to a greater degree of hydration and higher compressive strength.

9: LITERATURE REVIEW (KEY STUDIES III)

- **Dayalan & Buellah (2014):** Reported that internally cured concrete achieved 20% higher compressive strength compared to plain concrete.
- **Durability Findings:** This study also noted a 55% reduction in chloride penetrability at 180 days.

10: RESEARCH OBJECTIVES

- **Primary Goal:** To study the shrinkage behavior and properties of HPC using the internal curing method.
- **Specific Targets:**
 - Determine compressive, flexural, and shrinkage behavior of M50 grade concrete.
 - Find the optimum replacement percentage of LWA for maximum strength and durability.

11: METHODOLOGY

The research followed a systematic flow:

1. **Literature Collection.**
2. **Material Procurement** (Silica Fume, Vermiculite).
3. **Mix Design** (M50 Grade).
4. **Experimental Studies:** Compressive, flexural, shrinkage, acid attack, and sulphate attack tests.

12: EXPERIMENTAL MIX DESIGN (M50)

- **Target Strength:** Calculated at 58.25 N/mm².
- **W/C Ratio:** Adopted at 0.35.
- **Cement Replacement:** Cement was partially replaced with 10% Silica Fume to enhance performance.
- **Fine Aggregate Replacement:** Vermiculite used at varying percentages (0%, 5%, 10%, 15%, 20%).

13: CASTING AND COMPACTION

- **Preparation:** Molds (cubes, beams, prisms) were cleaned and oiled before filling.
- **Layering:** Concrete was filled in three layers, with each layer compacted by hand tamping or vibration to expel entrapped air.
- **Finishing:** Surfaces were leveled with a trowel and covered to prevent evaporation.

14: CURING PROCESSES

- **Water Curing:** Specimens submerged in clean water at 27°C after initial demolding.
- **Internal Curing:** Specimens kept in non-exposed areas and covered with plastic sheets, relying on pre-soaked vermiculite for "inside-out" moisture supply.



15: RESULTS (COMPRESSIVE STRENGTH)

- **Optimum Replacement:** The 10% vermiculite replacement was found to be most effective.
- **Performance Increase:** Internally cured concrete showed a **7.3% higher** compressive strength than plain concrete.
- **Hydration:** The gain is attributed to continuous hydration at later ages due to the stored water in the vermiculite.

16: FLEXURAL STRENGTH RESULTS

- **Improvement:** Flexural strength for internal curing was **8.3% higher** than the control concrete.
- **Water Curing Comparison:** For water-cured specimens, the increase was lower at 5.8%.

17: SHRINKAGE TEST RESULTS

- **Measurement:** Conducted on 100 x 100 x 286 mm prism specimens.
- **Significant Reduction:** At 28 days, vermiculite in internal curing reduced shrinkage by **47%** compared to normal concrete.
- **IC vs. Water Curing:** Internal curing consistently provided better results than external water curing.

18: DURABILITY TEST - ACID AND SULPHATE ATTACK

- **Acid Attack:** Measured by weight reduction and strength loss after chemical immersion.
- **Sulphate Attack:** 5% and 10% vermiculite replacements showed the best resistance, with less weight and strength reduction compared to the control.
- **Strength Retention:** Before sulphate attack, 10% IC concrete had 60.32 N/mm² strength, dropping only to 58.10 N/mm² after immersion.

19: NON-DESTRUCTIVE TESTING (NDT)

- **Rebound Hammer:** Used to evaluate the strength and quality of hardened concrete without damage.
- **Purpose:** Assessing the condition of the existing structure and investigating micro-cracks or progressive deterioration.



20: RESULTS AND DISCUSSION

The results of the experimental investigation namely compressive strength, Tensile strength, flexural strength, shrinkage test, acid attack, sulphate attack and Ndt were discussed.

Compressive strength test results

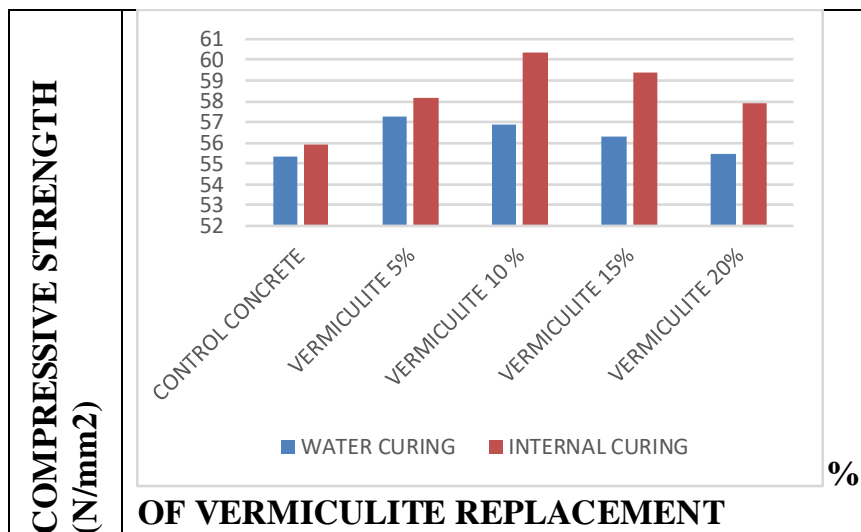
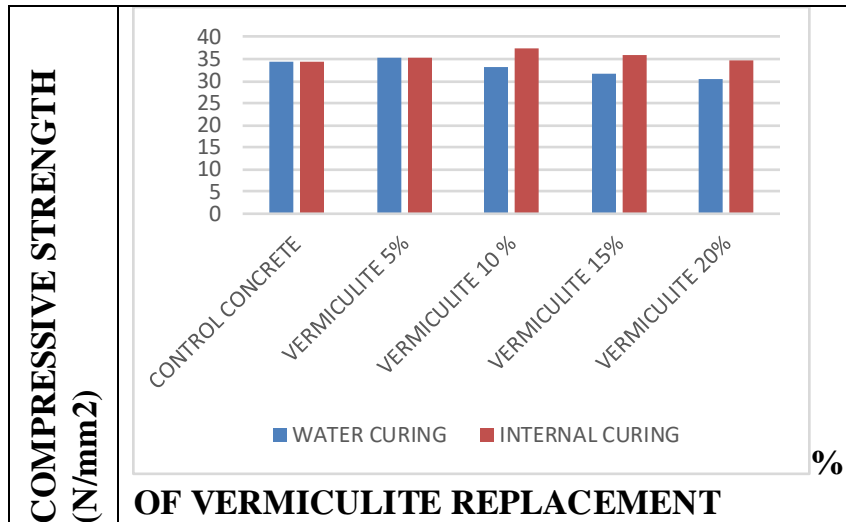
Compressive strength of concrete cubes was casted and results for 7th & 28th Day were noted. 3 samples were prepared for each mix proportion. Compressive Strength of concrete specimens

Flexural strength test results

Flexural strength of concrete beams was casted and results for 7th & 28th day were noted. From compressive strength test results, I had found that optimum replacement for fa with vermiculite in water curing and internal curing was 5% and 10%. This percentage replacement of light weight aggregate was taken preparing the beam specimen, 3 samples were prepared for each mix proportion. Flexural strength of concrete specimens.

Flexural strength of concrete specimens (Internal curing)

Vermiculite replacement (%)	Name of the specimen	Compressive strength (N/mm ²)		Mean strength (N/mm ²)	
		7 days	28 days	7 days	28 days
-	Cube 1	4.34	6.97	4.38	6.91
	Cube 2	4.38	6.91		
	Cube 3	4.42	6.86		
10	Cube 1	4.76	7.53	4.74	7.54
	Cube 2	4.73	7.49		
	Cube 3	4.69	7.59		



21: CONCLUSIONS

- **Superiority:** Internally cured concrete is proven to be better than conventional water-cured concrete.
- **Strength & Cracks:** Addition of vermiculite increases strength and significantly decreases shrinkage.
- **Recommendation:** 10% vermiculite replacement is the optimum level to provide sufficient water for hydration and crack reduction.
- **Homogeneity:** HPC is more homogeneous and has fewer initial flaws (pores/cracks) than normal concrete.

22: REFERENCES

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