

Early Age Curing Temperature Sensitivity and Strength Characteristics of Rapid-Hardening Concrete Materials

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PROBLEM STATEMENT & OBJECTIVES

Why this matters:

- Traditional concrete systems often fail to meet the stringent requirements of modern repair schedules, necessitating innovative approaches.
- Rapid-hardening concretes enable fast pavement repairs but risk long-term durability due to accelerated hydration.

Key knowledge gap: How do curing temperatures (10°C, 22°C, 35°C) affect early strength (first few hours) vs. 28/90-day (long-term) performance?

Study Aim:

- Quantify the trade-off between early-age strength gain and long-term durability of rapid-hardening materials under controlled thermal curing regimes.
- Correlate thermal signatures with strength development patterns

MATERIALS & METHOD

Materials tested:

- Calcium sulfoaluminate (CSA) cements (C1, C2)
- Proprietary-Prepackaged repair materials (X1-X6)
- Polymer-Based systems (P1, P2)
- Type III OPC (control) (T1)

Curing regimes:

10°C (cold), 22°C (ambient), 35°C (hot) — both moist and air-cured

Testing (per ASTM):

- Compressive strength: 2h, 4h, 24h, 7d, 28d, 91d (ASTM C39)
- Hydration Behavior: Internal temperature logged every 5 min for 24h
- Mechanical Properties: Flexural, tensile, shrinkage, and elastic modulus

Specimens: Field Validation: Full-scale slabs + 4×8" cylinders, 4×4×14" beams

RESULTS & DISCUSSION

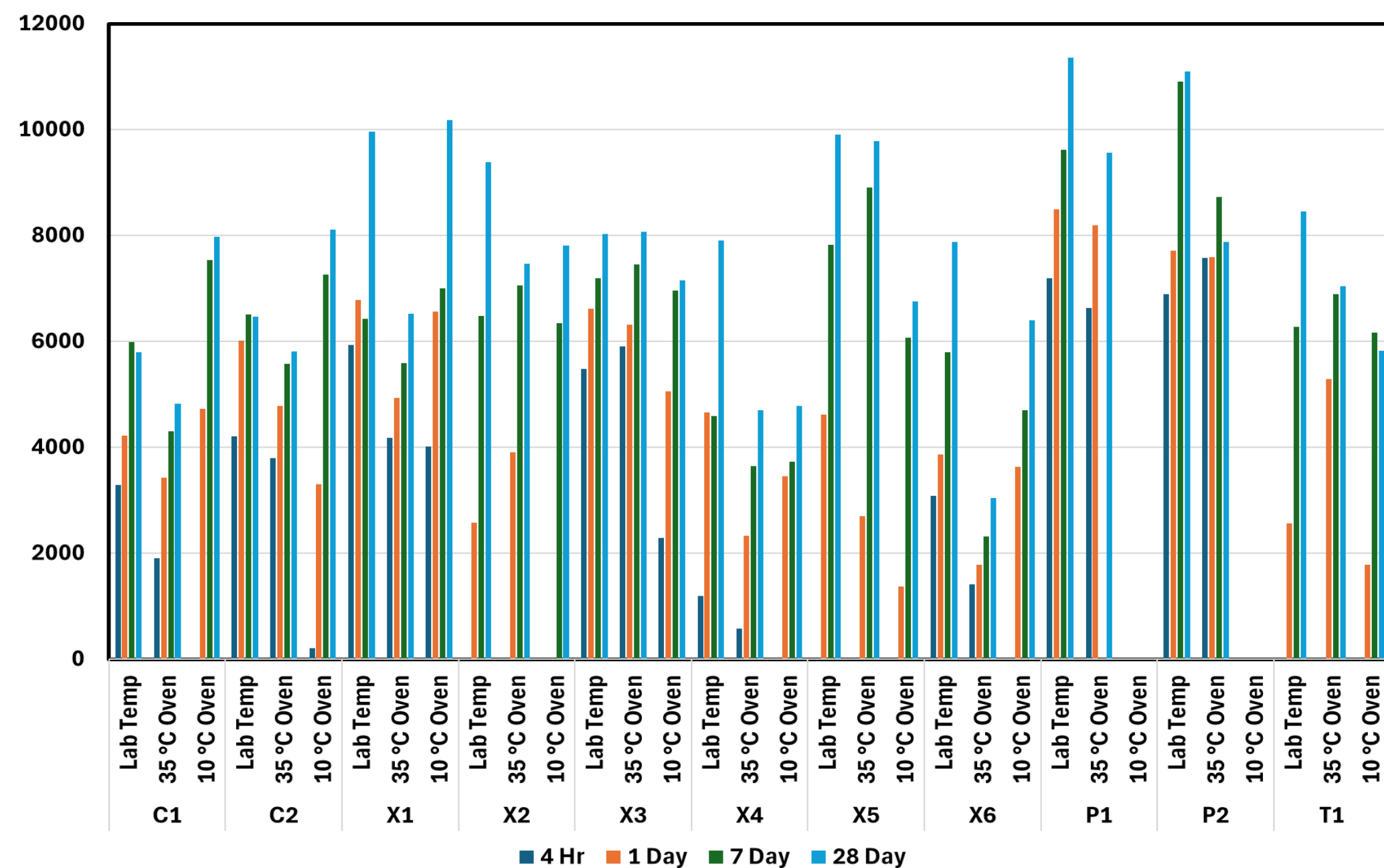
Early-Age (4–24 h):

- 35°C: Strength ↑ early (20–25 MPa by 4h)
- 10°C: Delayed gain but higher ultimate strength

Long-Term (28–90 d):

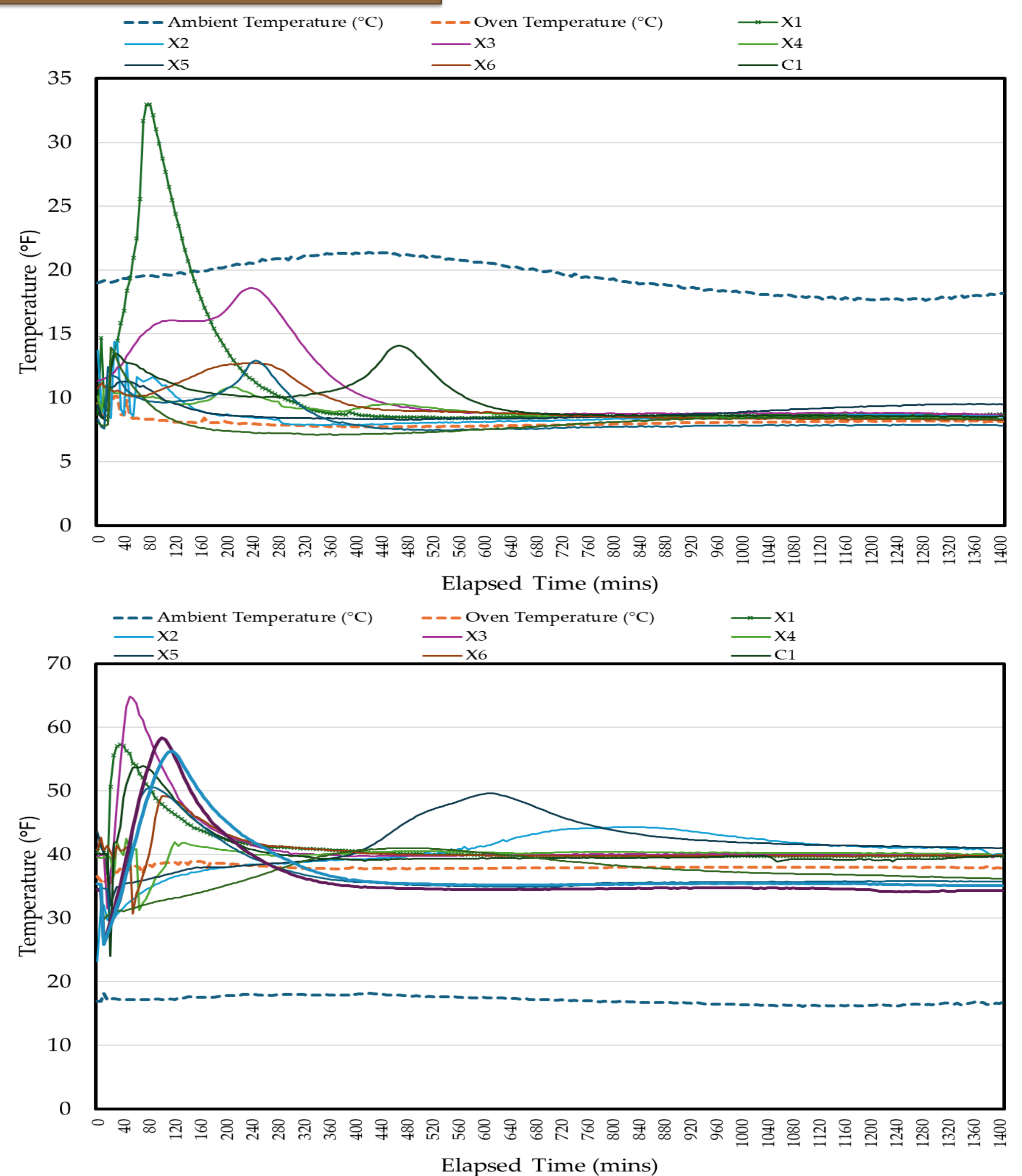
- 35°C curing ↓ 28-day strength by up to 15%
- 10°C curing ↑ 28/90-day strength by 8–12%
- CSA-Based mixes: 10°C air-cured reached >9,000 psi vs. ~5,800 psi at 22°C

Compressive Strength Comparison Across Different Curing Temperature



Bimodal Thermal Profiles Observed:

- Peak 1: <2h (initial ettringite formation).
- Peak 2: 6–8h (secondary reaction) → indicates complex hydration kinetics.
- Curing temperature has nuanced impact of strength gain ratio.



CONCLUSION

- Elevated curing (35°C) **accelerates early strength but harms long-term performance.**
- Cooler curing (10°C) **enhances ultimate strength**, especially for CSA systems.
- Moisture retention is critical in hot weather; insulation beats cold exposure in winter.**
- It is important to note the trade-offs between rapid-strength gain and cracking potential of rapid-strength systems and adjust curing regimes as required.

Recommendations for Practice:

- In hot climates: seal/cover patches to retain moisture.
- In cold climates: use insulating blankets to trap exothermic heat.

FUTURE WORK

- Microstructural analysis (SEM/XRD/TGA) to link thermal profiles to phase evolution (ettringite, microcracks).
- Develop field curing guidelines balancing reopen time and durability.

KEY REFERENCES

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