Rowan University
CENTER FOR RESEARCH & EDUCATION IN ADVANCED TRANSPORTATION ENGINEERING SYSTEMS

Electric Curing of Concrete: Methodology, Validation, and Field Scale-Up

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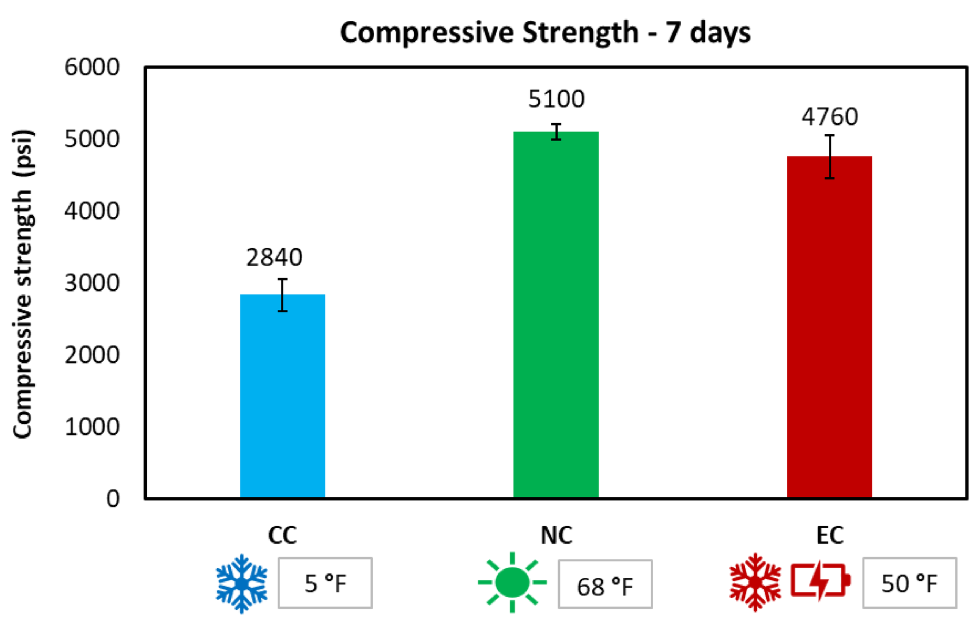
INTRODUCTION

- Curing concrete in subzero temperatures slows hydration, reducing strength by up to 50% and increasing microcracking risk. Electric curing offers an efficient alternative by generating internal heat through the Joule effect, but its field use remains limited by cost, safety, and scalability challenges.



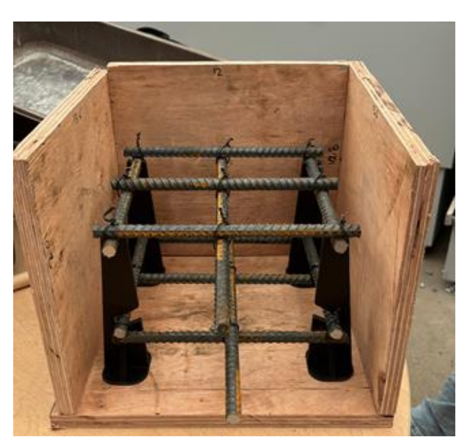
Freeze-Induced Damage in Concrete

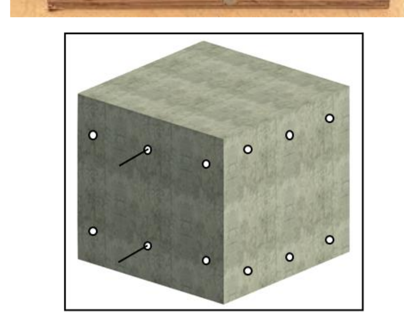
Coupal, J. (2015, January 22). Practical advice for pouring concrete walls in cold weather – Boston, MA. A-1 Foundation Crack Repair, Inc.

OBJECTIVES

This research introduces an Electrically Controlled Reinforced Concrete (ECRC) system that:

- Uses reinforcement steel as embedded electrodes for uniform heating.
- Employs a low-voltage thermostat-based controller for self-regulating temperature.
- Develops a scalable energy-balance theoretical model that enables prediction of the electrical power demand for curing concrete elements of any size or geometry under real field conditions.





THEORETICAL FRAMEWORK

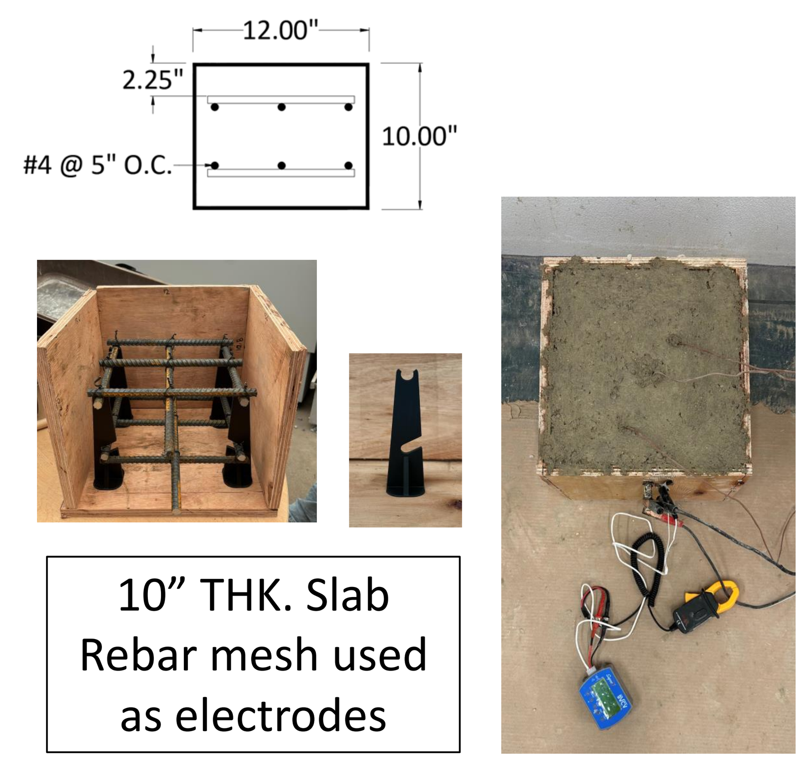
The ECRC model is based on energy exchange principle between generated heat and heat losses.

- Joule Heating: $W_E = \frac{U^2 t}{R}$
- Heat Loss: $W_c = Ah(T - T_r)t$
- Required Heat: $Q = mc(T_f - T_0)$

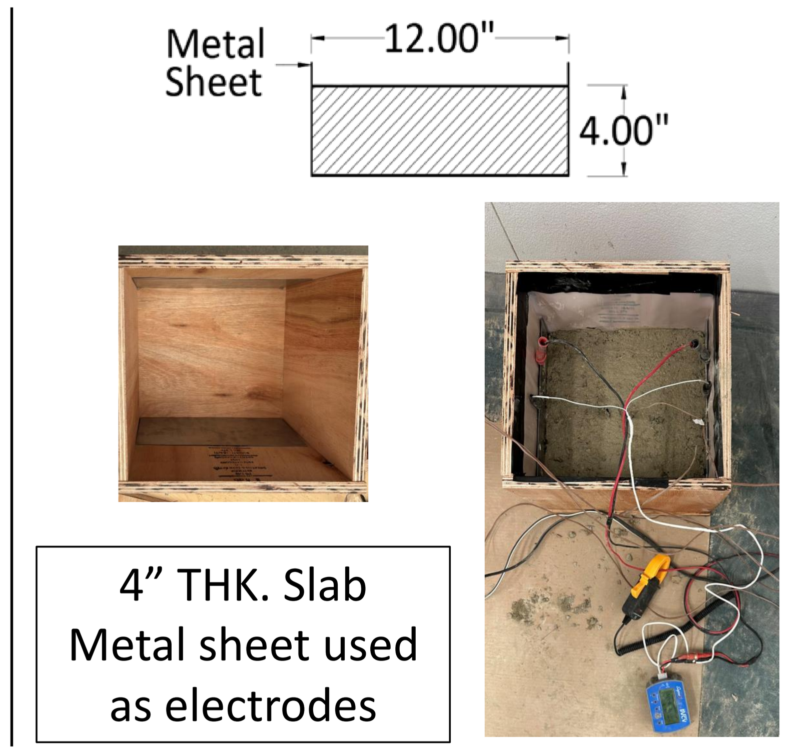
$$\rho WLDc\frac{dT_c}{dt} = \frac{V^2}{rL} + \dot{q}_{HoH}WLD - WLh\Delta T_{conv}$$

EXPERIMENTAL SETUP

- Concrete slabs (12″ × 12″ × 10″) were cast and instrumented to evaluate the heating performance of the ECRC system.



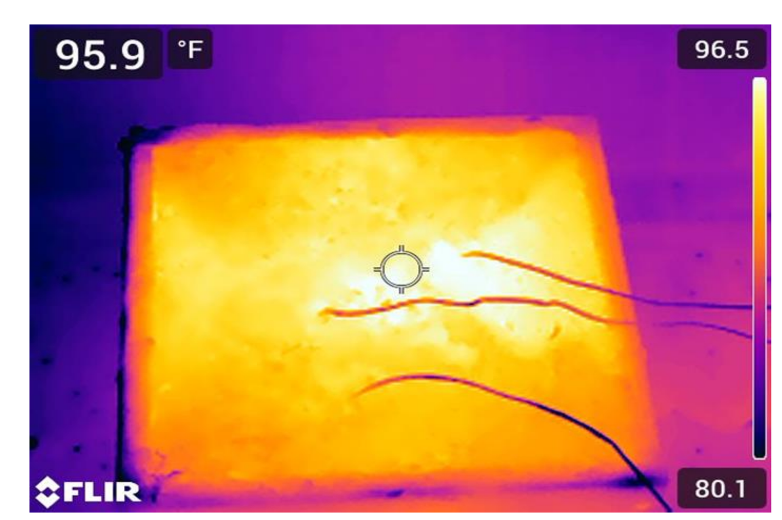
10” THK. Slab
Rebar mesh used as electrodes



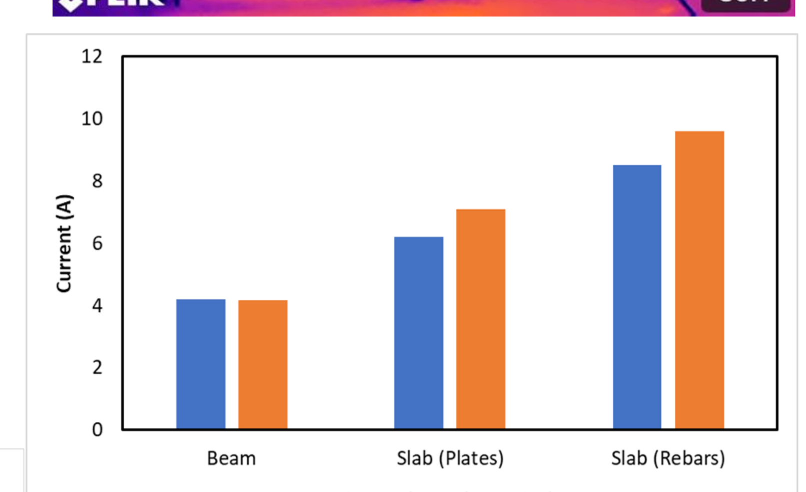
4” THK. Slab
Metal sheet used as electrodes

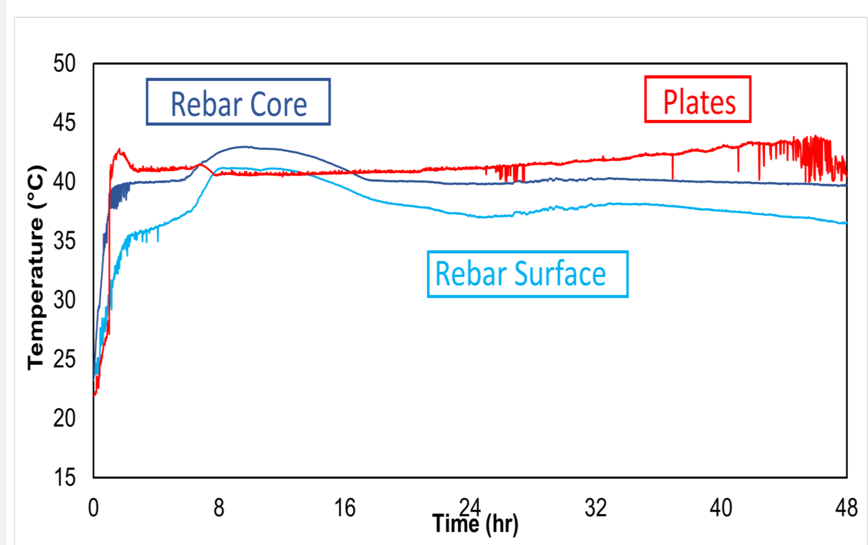
RESULTS

- Both electrode setups increased concrete temperature—plates produced side-dominant heating, while rebars achieved uniform heating throughout the slab.



- The theoretical model accurately predicted the current required for heating, with experimental values within ±1 A of predictions.





- Rebars provided uniform heating even without carbon fiber (0% CF), whereas plate electrodes required 0.5% CF to reach similar temperatures.

RESEARCH OVERVIEW

Phase I – Beam Experiment Data

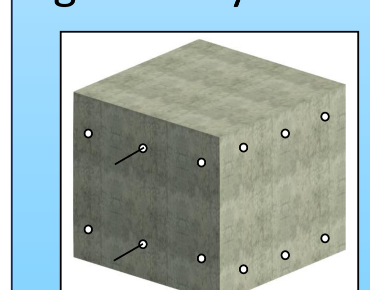
- Laboratory-scale beam specimens.
- Conducted in cold chamber (–15 °C).
- Studied temperature and electrical behavior under realistic cold-curing conditions.
- Output → foundational data for model development

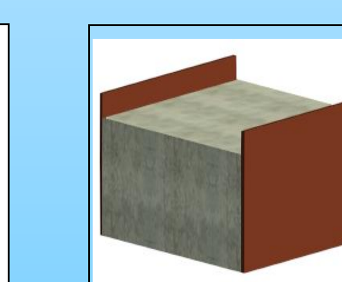
Theoretical Model

- Developed an energy-balance model linking electrical input and thermal response.
- Parameters include Joule heat generation, conductive/convective losses, and time-varying resistivity
- Output → predicted current required for stable curing

Scale-Up Application (Slab)

- Concrete slabs (12”×12”×10”) tested in lab from 20–40 °C.
- Two configurations: plate vs. rebar electrodes.
- Rebar system achieved 40 °C even at 0 % CF, plates required CF.
- Output → validated model under scaled-up, practical geometry.





Model Validation

- Compared predicted vs. experimental currents (± 1 A agreement)
- Verified performance using Phase I beam (cold chamber) and Phase II slab data
- Output → model confirmed scalable and accurate for field-scale implementation

CONCLUSION AND ONGOING WORK

Conclusion:

The ECRC system provides an efficient and low-cost solution for cold-weather concrete curing. By using existing reinforcement as embedded electrodes, it removes the need for conductive additives like carbon fiber or complex heating setups. This simple integration reduces material and installation costs while ensuring uniform heat distribution. The scalable energy-balance model further allows accurate prediction of the required current or power for any structural size, making the system practical and field-ready.

Ongoing work:

- Conduct microstructural studies to assess effects of electric curing on concrete structure.
- Examine rebar durability and conductivity after heating.
- Perform numerical simulations to examine heat and temperature distributions within Large-Scale slabs and complex structural elements.

Acknowledgement

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