Internal Relative Humidity Profiling and Measurement Techniques in Concrete

R.A. Rodden, D.A. Lange, Z.C. Grasley

Objectives
- Develop a computer independent multiplexer capable of measuring and logging relative humidity and temperature data at a user definable interval
- Test a novel parallel to surface sampling technique
- Use collected data to model RH profiles and thus check validity of current sampling techniques

Theoretical Background
- Once cement matrix pores larger than 50nm in diameter are emptied, curved menisci develop
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- Pore fluid pressure is fundamentally related to internal relative humidity (RH)
  \[ p'' = p' - \frac{v}{RT} \ln(\frac{R_H}{R_H'}) \]
  \[ p'' = \text{pore fluid pressure} \]
  \[ p' = \text{vapor pressure (constant)} \]
  \[ R = \text{internal RH} \]
  \[ T = \text{Temperature in Kelvin} \]
  \[ v = \text{moisture mass of water} \]
- Measurement of internal relative humidity at different points and depths allows us to model drying stress gradient

Research Approach
- Computer independent multiplexer developed using a previous computer dependent system as a basis
  + Hardware improvements:
  - Sufficient battery selected
  - Controlled RH chambers constructed using sealed plastic containers and salt solutions (e.g. solution of NaCl gives 75% RH at 25°C)
- Sensors set to sample different depths within concrete, different depths from surface, and one set to sample from the edge

Research Results
- Sensing System
  - Since computer independent system new, robustness tested
  - Left sampling 8 sensors on battery power for over three weeks without incident
  - Current wiring scheme allows user to either collect data on to EEPROM and retrieve when finished or continuously collect using a computer and readily available software (i.e. LabView)
- Packing System
  - Normal packing procedure used in the past, but new side sampling packing procedure had difficulties with:
    + Sealing (Gore-Tex/straw interface difficult to seal)
    + Sampling (ensuring parallel to surface)
    + Positioning (close to edge of mold)
  - For these reasons, this novel sampling technique is difficult to manage in field application

Development of Computer Independent Internal Relative Humidity and Temperature Multiplexer

Hardware Design:
- Microcomputer: BK-24 Microprocessor
- RH/Temp Sensors: Sensirion SHT75
- External Memory: Rabbit SF-1004
- Battery: MU-1 (12V and 35aH)

Programming Logic
- Sensors sampled at user defined interval
- Data stored immediately on BK-24 (volatile)
- Once 512 bytes written, data sent to SF-1004
- Data on SF-1004 not lost in power outage

Current Statistics
- As wired, can sample 11 sensors
- 4MB EEPROM (SF-1004) stores over 65,000 sampling, lasting over 1.5 years at a 6-minute interval
- MU-1 Battery will last over two months
- Integrating a solar panel will allow battery to run indefinitely

Sampling Technique Validation
- Test to investigate if heat of hydration within relatively thick section will cause sensor error
  + Sensors set up in BIC brand pens with Gore-Tex cap to allow vapor but not moisture to enter the sealed packing
  + Sensors placed at:
    - Mid cross section (center) while sampling 1/4''
    - At surface (deep) while sampling 1/4''
    - At surface (deep) while sampling 1/2''
- Test new side-sampling technique
  + Sensor set up in BIC pen with Gore-Tex sleeved straw out of its top
  + Sensor placed at:
    - Parallel to surface (edge) while sampling 1/4''

Conclusions
- Current sampling method valid if consistent throughout experimental program
- Due to complexity of implementing side sampling method, it is inefficient
- More tests necessary and different depth to model drying stress profiles

Potential Applications
- Conduct controlled tests in various RH chambers to back out drying dependency on environment
- Embed sensors in airfield concrete pavements at O’Hare International Airport as part of the O’Hare Modernization Program
- Analyzed data and construct model to predict concrete airfield slab behavior under moisture and temperature variations
- Testing effectiveness and durability of curing and sealing methods in the field
- Real time evaluation of drying during construction to investigate geometric and environmental effects
- Modeling pavement curling of roadways

Anticipated Applications
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