Durability Monitoring of Geopolymer Concrete Structures Using Embedded pH Glass Electrode Sensors

Never Stand Still

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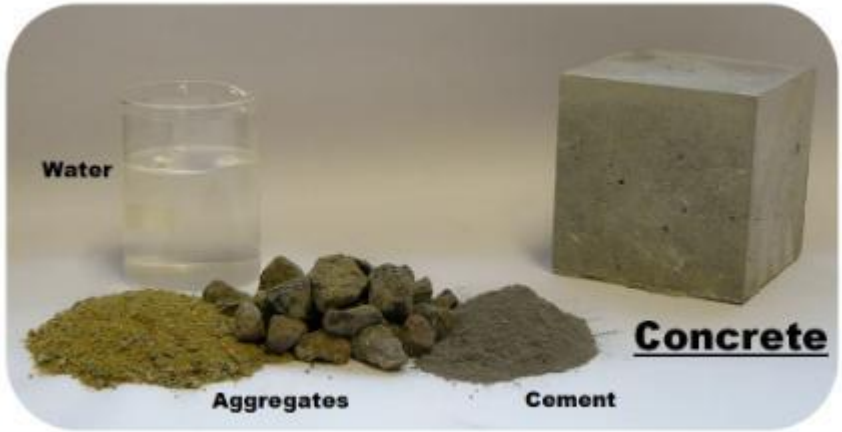
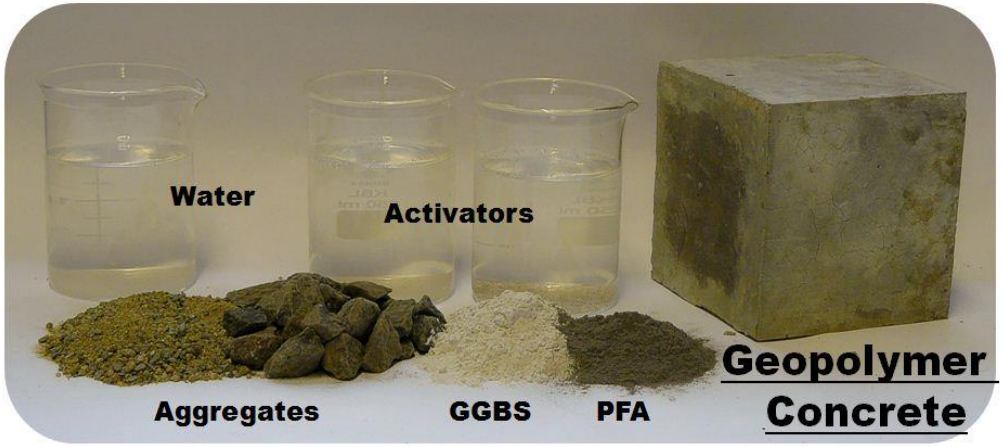
Introduction

- **Geopolymer concrete (GPC)**
  - Using a wide variety of waste materials as supplementary cementing materials, including fly ash (FA) from coal combustion, ground granulated blast furnace slag (GGBFS) from iron production and silica fume (SF) from ferrosilicon production.



Portland Cement Concrete



Geopolymer Concrete

(Geopolymer Research)

Introduction

- **Main advantages of GPC over Ordinary Portland cement (OPC) concrete**
  - Up to 80% carbon dioxide (CO_2) emission reduction

- **Superior chemical and physical characters**
  - Rapid development of mechanical strength
  - Fire resistance
  - Dimensional stability
  - Acid resistance
  - Etc.

Industrial emission

Introduction

- **Problem Definition**
  - The industry has not fully embraced GPC as a desirable construction material for replacing OPC concrete
  - Most of experiments and studies on GPC are laboratory-based whereas the performance in field might be different
  - Lack of the Australian GPC standard specifications in addition to the current standard (e.g. AS3600)

- **Research Objectives**
  - To investigate feasibility of using embedded sensors to monitor pH value of GPC
  - Achieve a comprehensive understanding of carbonation induced pH reduction of GPC

Literature Review

- pH value in OPC concrete
  - 11 – 13.5: A passive film is formed
  - 11: The corrosion begin
  - 9: The passive film disappear

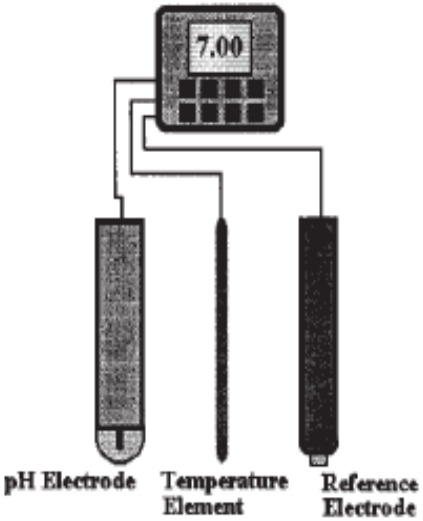
- Current pH measurement methods
  - Destructive: Grinding test
  - Non-destructive: Not available

Grinding test

pH Glass Electrode

- Conventional pH glass electrode is not suitable for OPC concrete
- The high alkaline condition (pH 13.5) in OPC will dissolve the glass electrode rapidly

- pH value in GPC is lower than the Portland cement concrete
  - pH of Geopolymer Concrete: 11.5 – 12.3 (Davidovits, 2005)
  - The pH value in OPC is 10 times or even 100 times stronger



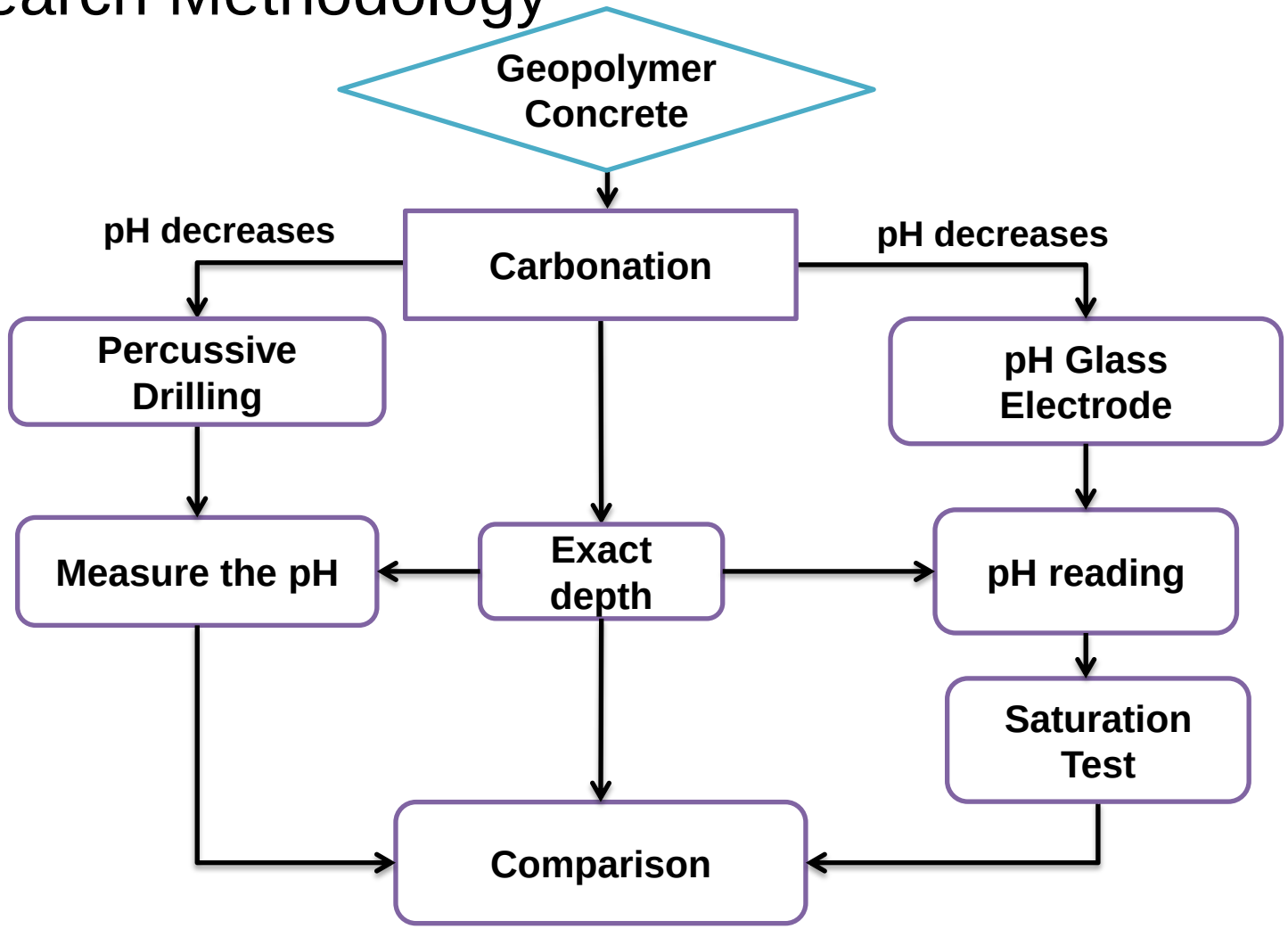
Glasss electrode Component (Emerson,2010)

Sensor Selection

- Emerson pH Glass Electrode
  - Operating temperature: -10°c to 100°c
  - Rugged sensor body
  - Suitable pH range: 0-14
  - Design for insertion/ Submersion
  - Low alkalinity error in pH 11-12

Emerson pH Glass Electrode (Model: General Purpose 3900)

Research Methodology



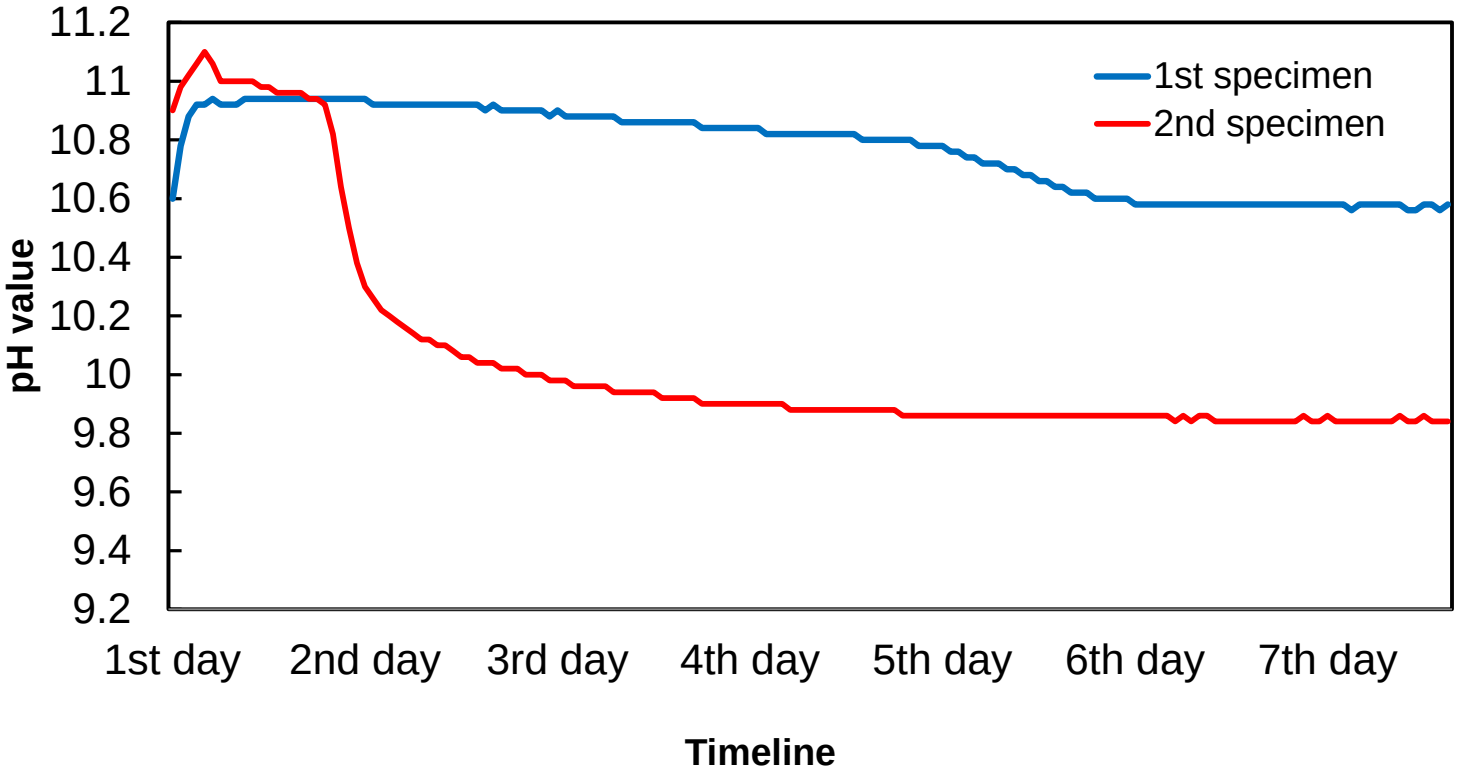
pH Measurement in Geopolymer Concrete

Experiment Setup

pH Sensor Embedment

Heat Curing in Oven (75°C for 18 hours)

Results and Discussions

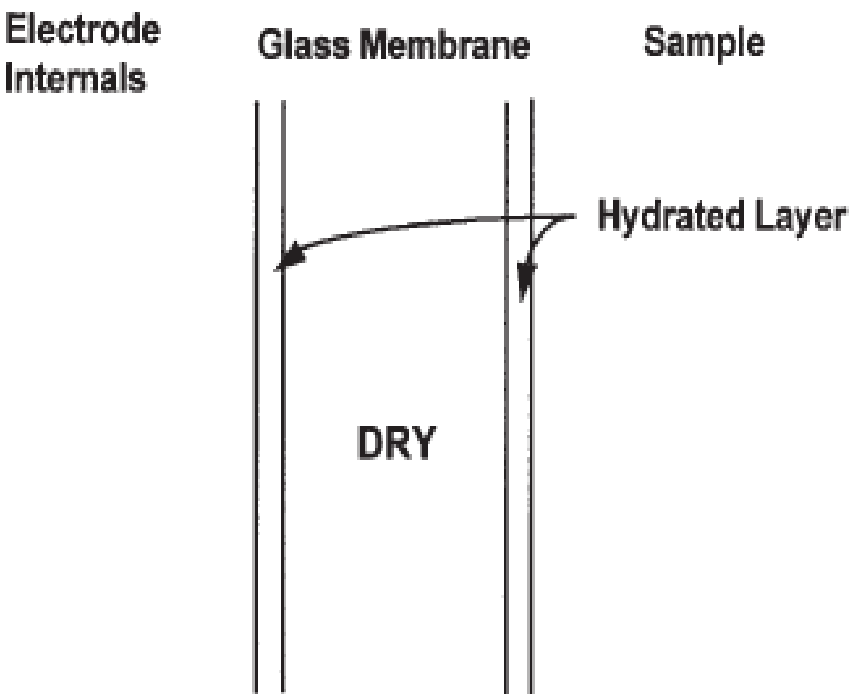


pH readings during 7-days curing

- 1ST specimen: embed at 100 mm, totally sealed
- 2nd specimen: embed at 20 mm, leaving the bottom evaporation

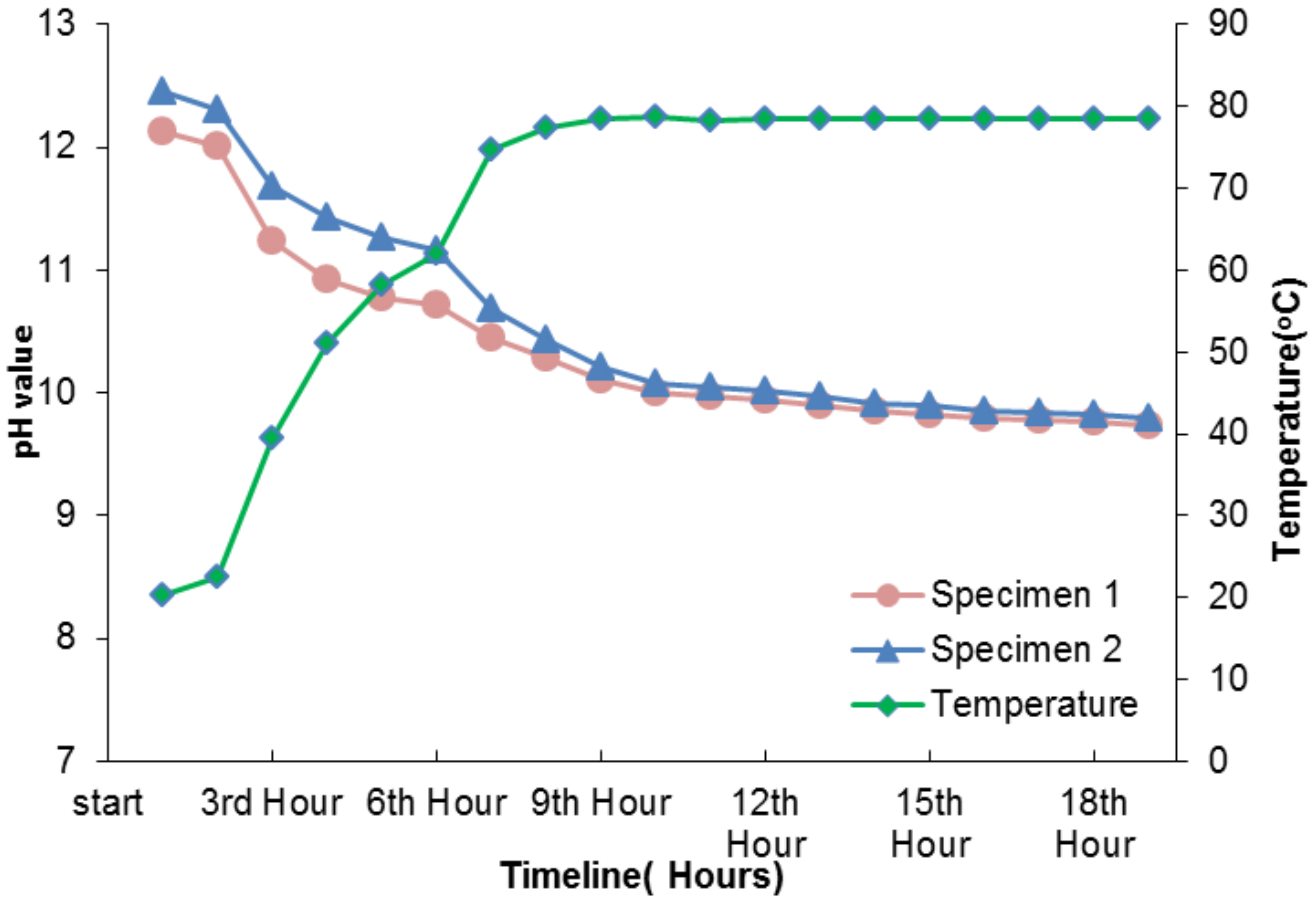
Results and Discussions

- **Dehydration Error**
  - Hydrated layer responds to pH changes
  - A dehydrate layer causes the high internal electrical resistance
  - Specimen requires periodic saturation



Cross section of pH Glass electrode (Emerson, 2010)

Results and Discussions



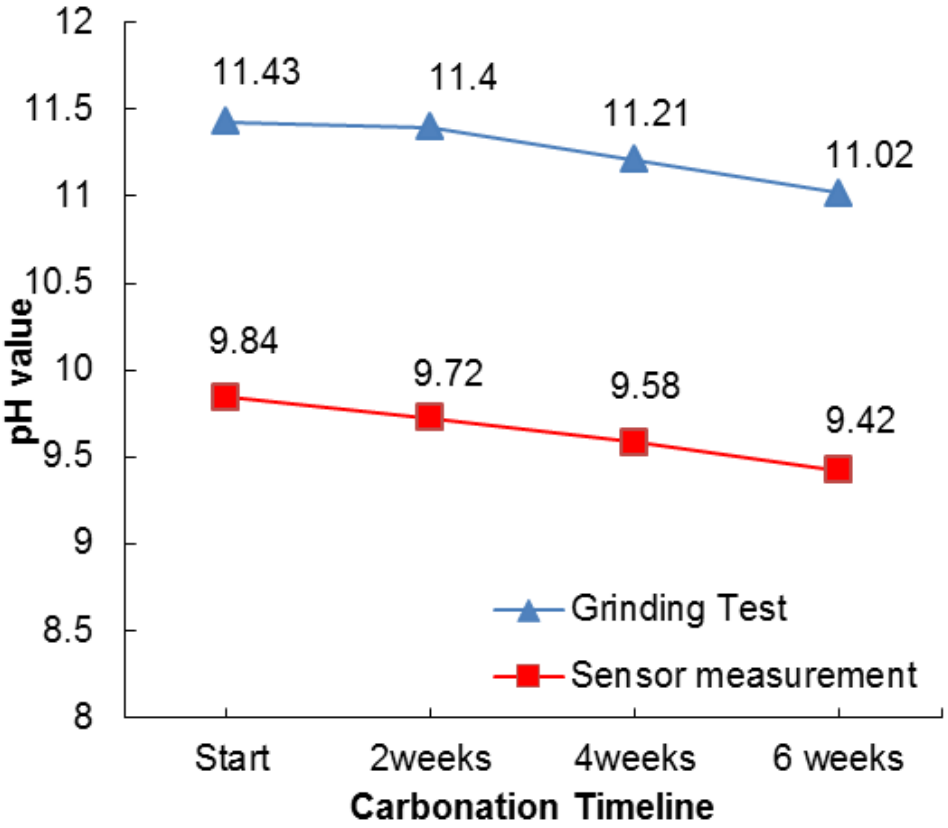
Sensor pH Reading VS. Temperature During Heat Curing

Experiment Setup

Carbonation Testing of GPC Specimen (1% CO_2; 23°C;52%RH)

Results and Discussions

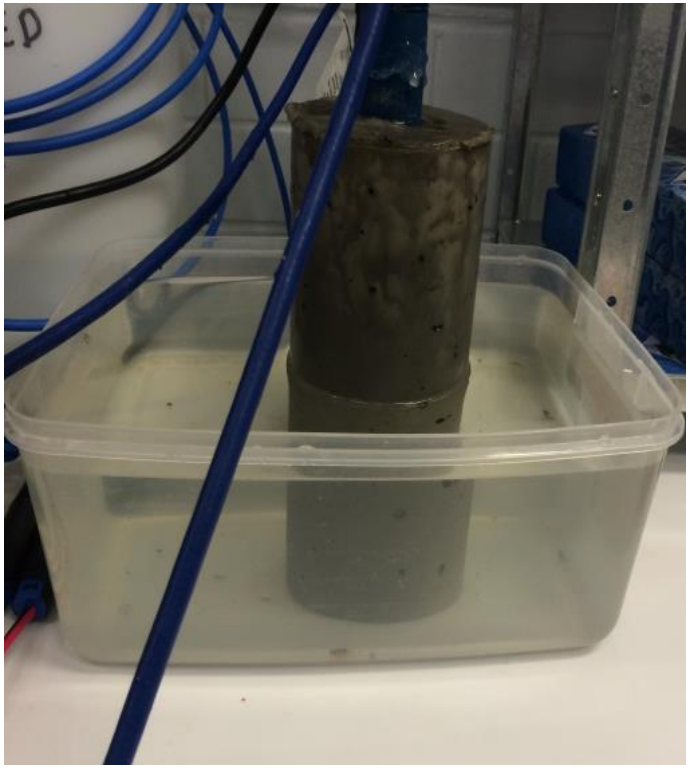
- **Carbonation result of 20mm**



6 weeks carbonation from pH sensor and grinding test (1% CO_2; 23°C;52%RH)

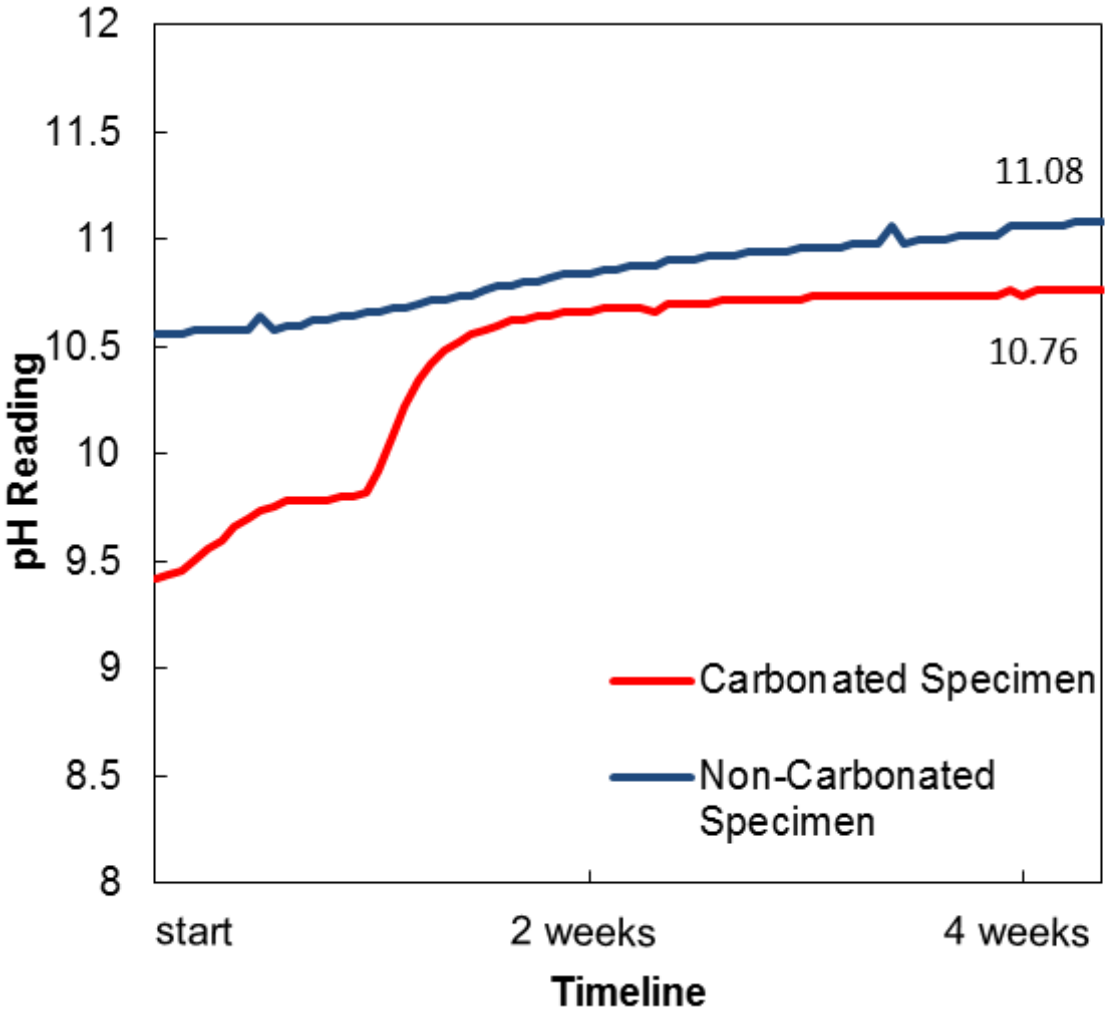
Experiment Setup

- **Saturation Tests**



Saturation on Specimen

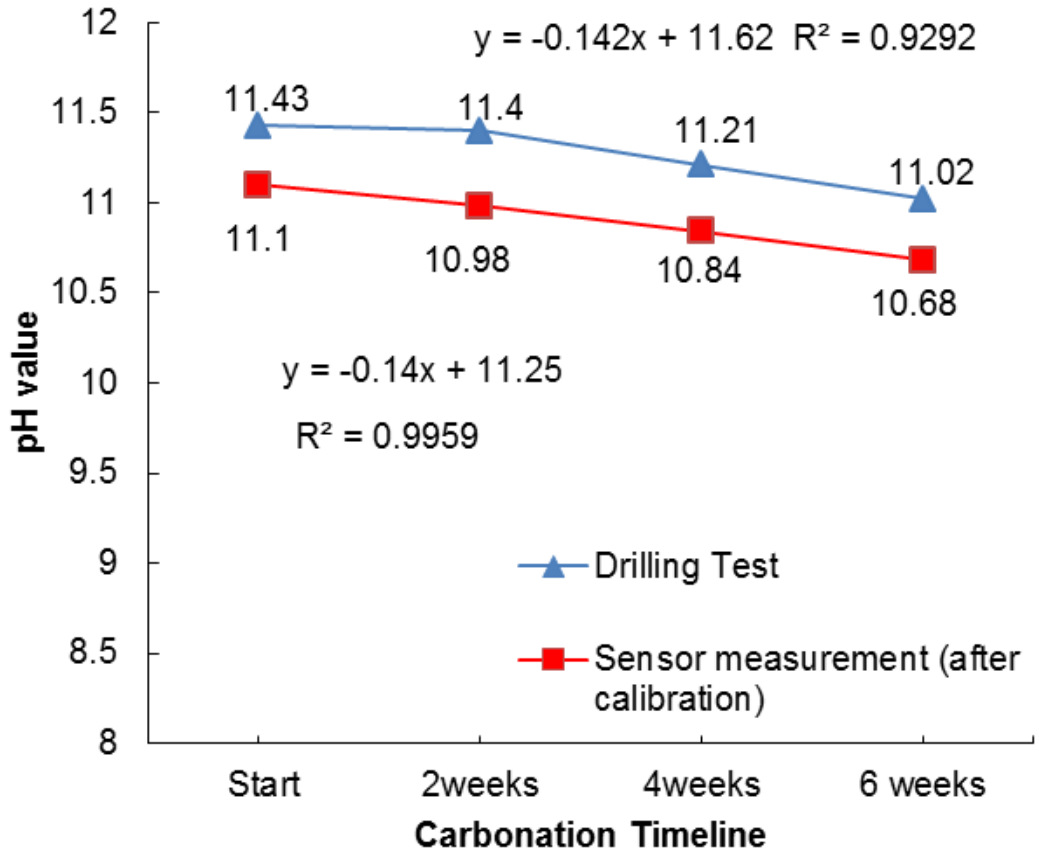
Results and Discussions



Carbonated pH reading after saturation

Results and Discussions

- **Diffusion Speed (0.07unit/week)**



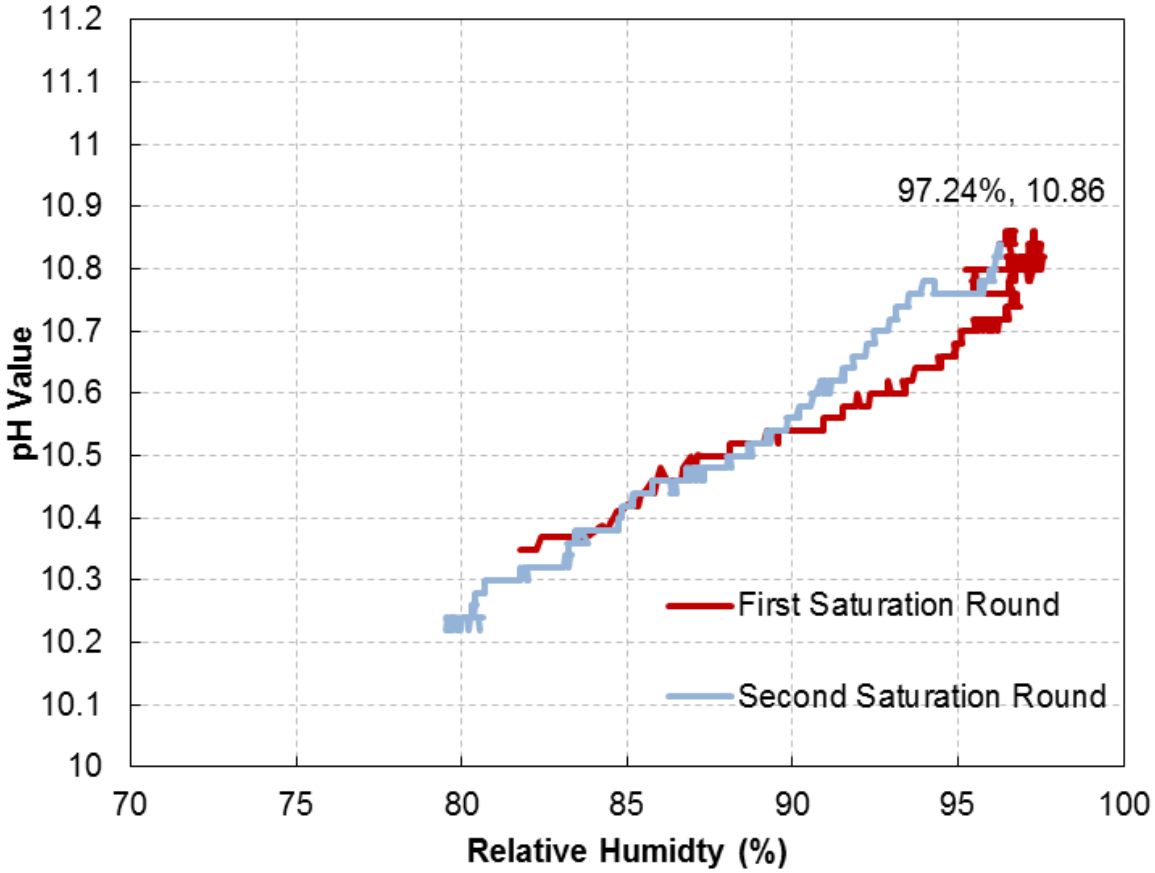
Calibrated Carbonation Result at 20 mm Depth

Experiment Setup

Measurement System - pH and Humidity Probes

Results and Discussions

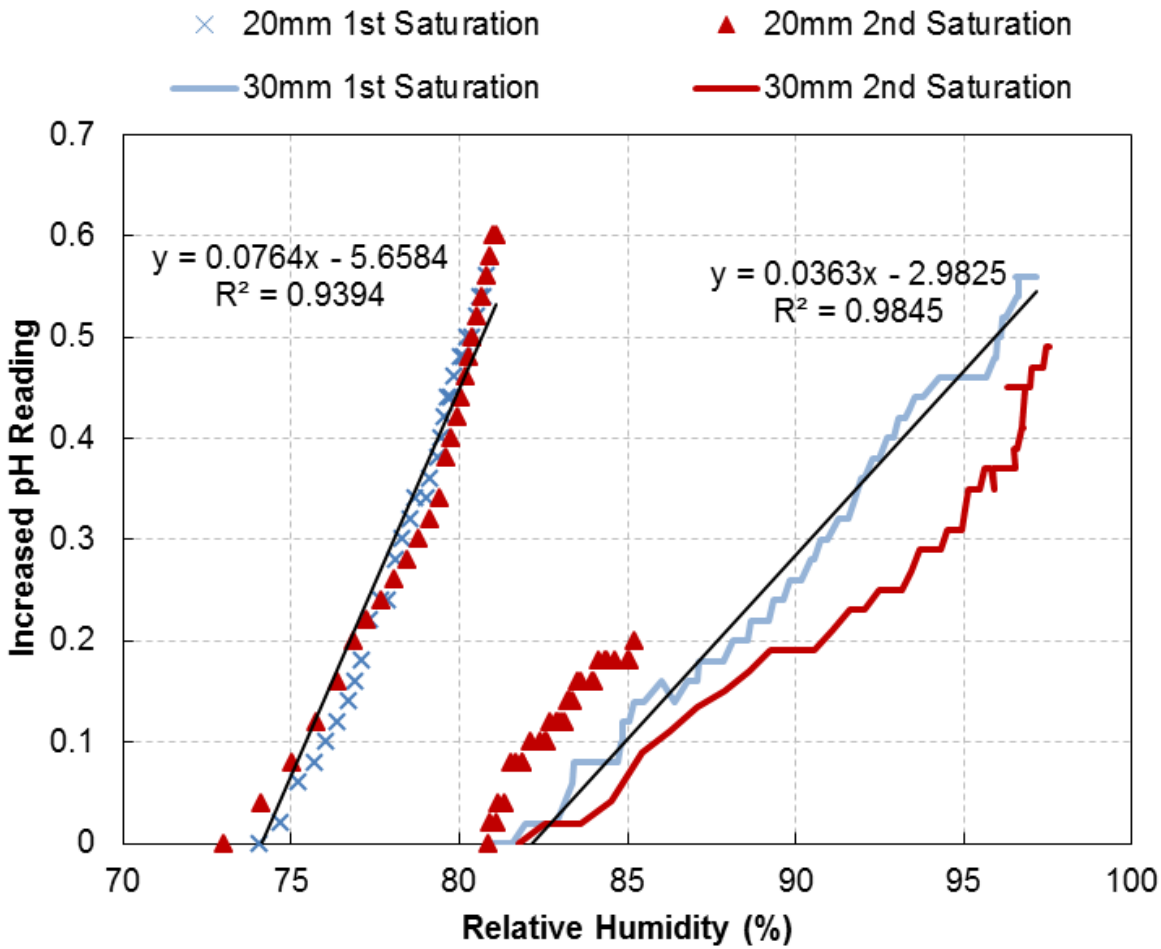
- **Sensor Stability**



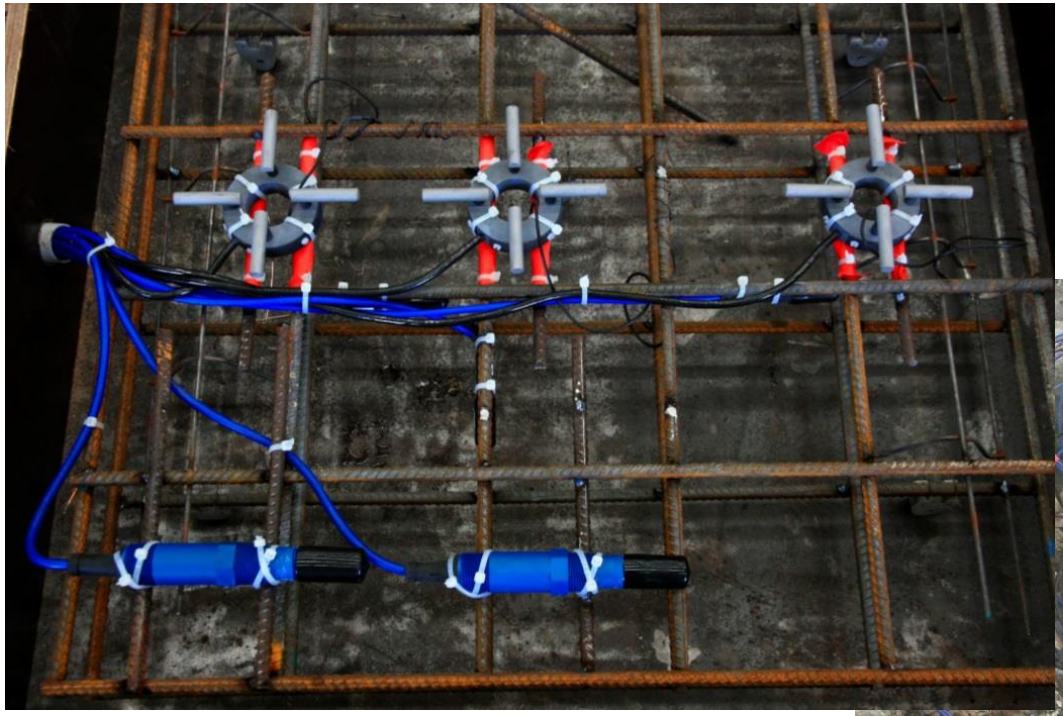
Re-Saturation Results in a 12 Months Aged GPC Sample with 30 mm Cover to Sensor

Results and Discussions

- **Correlation between pH Reading and Relative Humidity**



pH Sensing in Marine Environment



Boat Ramp at Port Macquarie, NSW

Conclusions

- First laboratory and field attempt that embeds a glass pH electrode into GPC for continuously measuring the real-time pH value variation
- The sensor has been successfully measuring the pH value in the GPC for an extended period of 12 months
- The sensor measurement accuracy in concrete is affected by three factors: moisture, temperature and carbon dioxide diffusion

Rapid Construction As-built Modelling Using Unmanned Aerial Vehicles (UAV)

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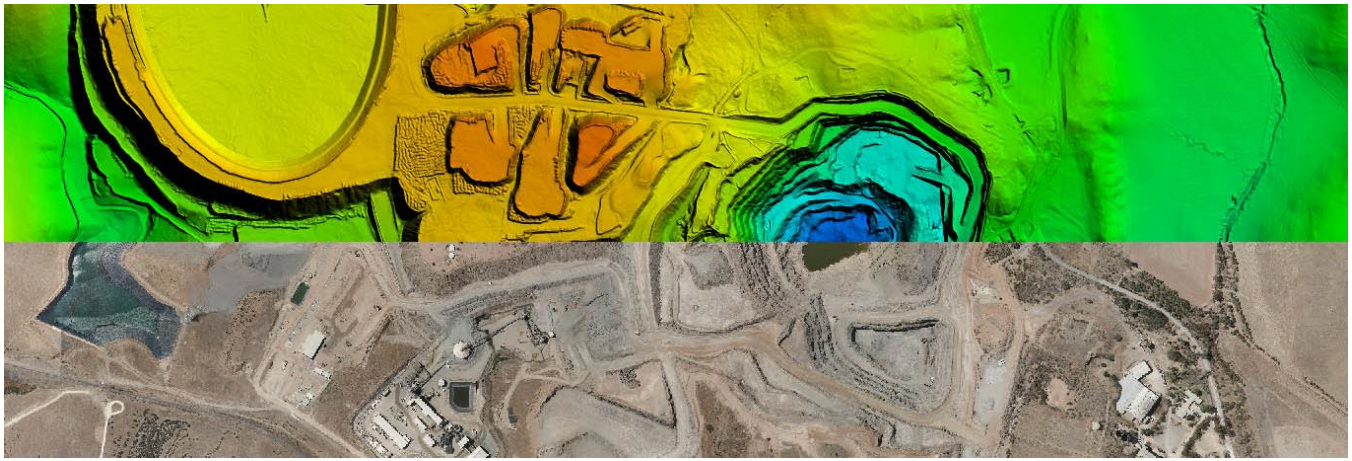
Dr. Johnson X. Shen, Lecturer
Engineering Construction and Management



Aerial Innovation in Construction Industry

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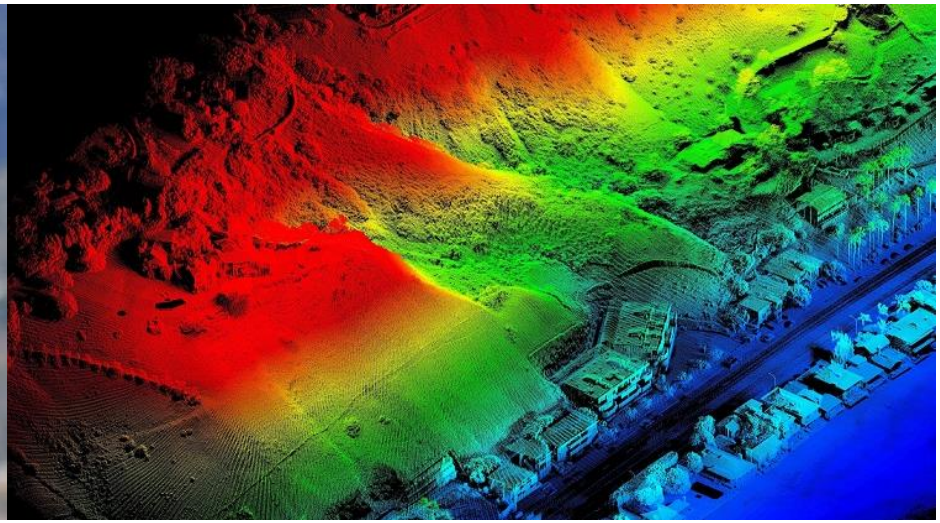
(Courtesy: THIESS)

3D Digital Construction Field Modelling Using Mobile LiDAR and Industrial UAV

- The project aims to develop 3D as-built digital elevation models (DEM) of construction field by incorporating mobile laser scanning techniques (LiDAR) with an industrial-grade unmanned aerial vehicle (UAV) platform



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3D Digital Construction Field Modelling Using Mobile LiDAR and Industrial UAV

Weight: 1.82 kg

Sensors:
- LiDAR (120m range)
- RTK-GPS
- MEMS IMU

Accuracy
- Centimetres

PHOENIX AERIAL SYSTEMS

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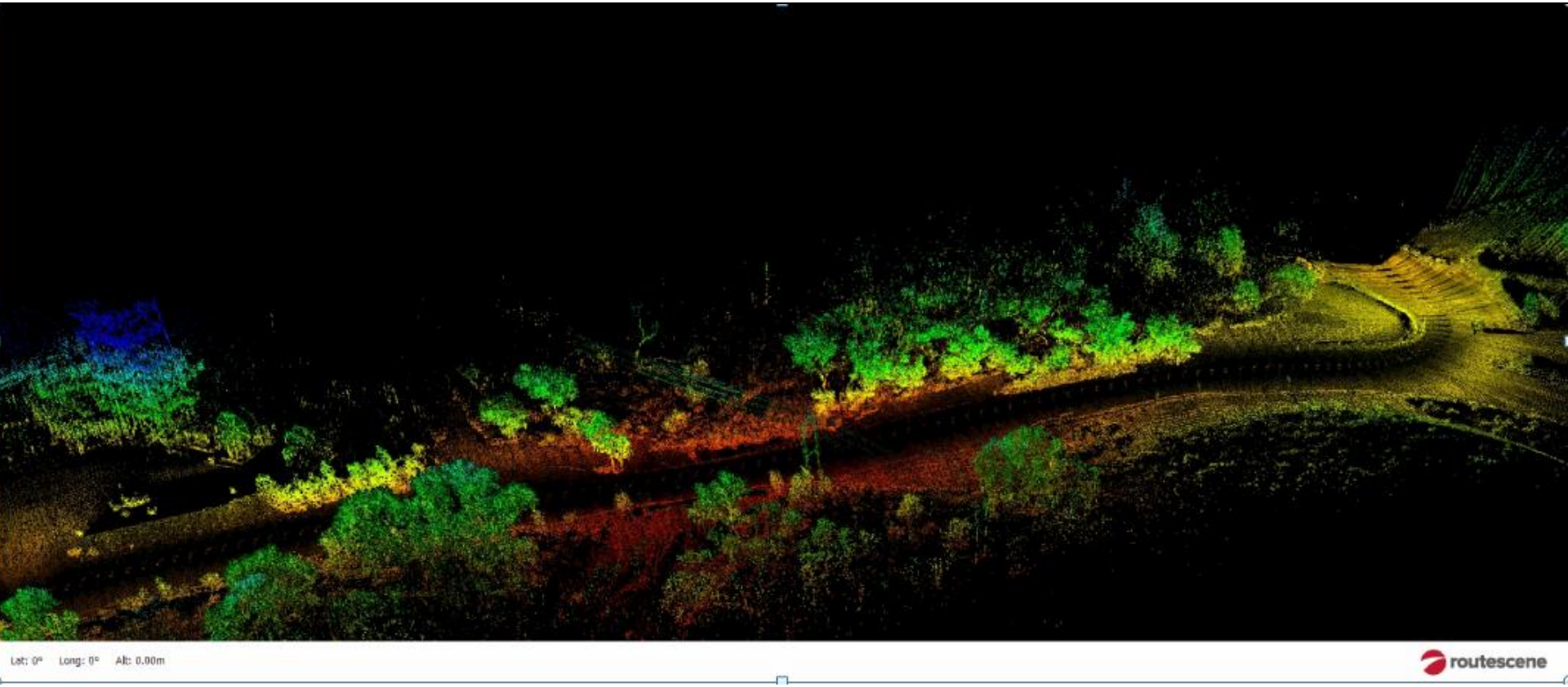
3D Digital Construction Field Modelling Using Mobile LiDAR and Industrial UAV



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3D Digital Construction Field Modelling Using Mobile LiDAR and Industrial UAV

Optical and Thermal Structural Inspections by Miniature UAV

- The project aims to inspect structural defects of high-rise buildings and aged infrastructure using quadcopter UAV with on-board RGB and infrared cameras

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UAV Resources at UNSW

- **Multirotor UAVs**

DJI Phantom 3 Professional

- Weight: 1.28 Kg
- Sensor: 12MP Camera
- Flight time: 20 min
- No. of Propellers: 4

Vulcan Heavy Lift Octocopter

- Weight: 14 Kg
- Sensors: LiDAR/Infrared Cam
- Flight time: 1 Hour
- No. of Propellers: 8

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UAV Resources at UNSW

- **Fixed Wing UAVs**

SenseFly eBee RTK

- Weight: 0.73 kg
- Sensor: 12MP RGB & NIR Cams
- Flight time: 40 min
- Wingspan: 0.96 m

SenseFly swinglet CAM

- Weight: 0.5 kg
- Sensors: 12 MP Camera
- Flight time: 30 min
- Wingspan: 0.8 m

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UAV Resources at UNSW

- **CASA Certified Remote Pilot and UAV Operator**
  - UAV Chief Pilot: **1**
  - Multirotor UAV Operators: **2**
    (8-20 kg Commercial UAV Grade)
  - Fixed Wing UAV Operators: **5**

Australian Government
Civil Aviation Safety Authority

AUSTRALIAN ACUO CERTIFIED UAV OPERATORS

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Thank You! Any Questions?

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