Smart concrete roads through the use of sensors

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Smart concrete roads

- What is “smart”?
  - Use of sensors to support :
    - Client - Owner - Agency
    - Contractor
    - Road operator
  - In the context of:
    - Quality (avoiding to make mistakes)
    - Worksite management (duration of the works – putting in service)
    - Durability (longevity - service-life)
    - Maintenance, repair and preservation (asset management)
  - In the phase of:
    - Fresh concrete
    - Young (curing) concrete
    - Hardened concrete

What has been done?

- Use of sensors in concrete road construction
  - Temperature measurements in the roadway and different types of samples
    - Applications of rapid-hardening concrete (2002-2010)

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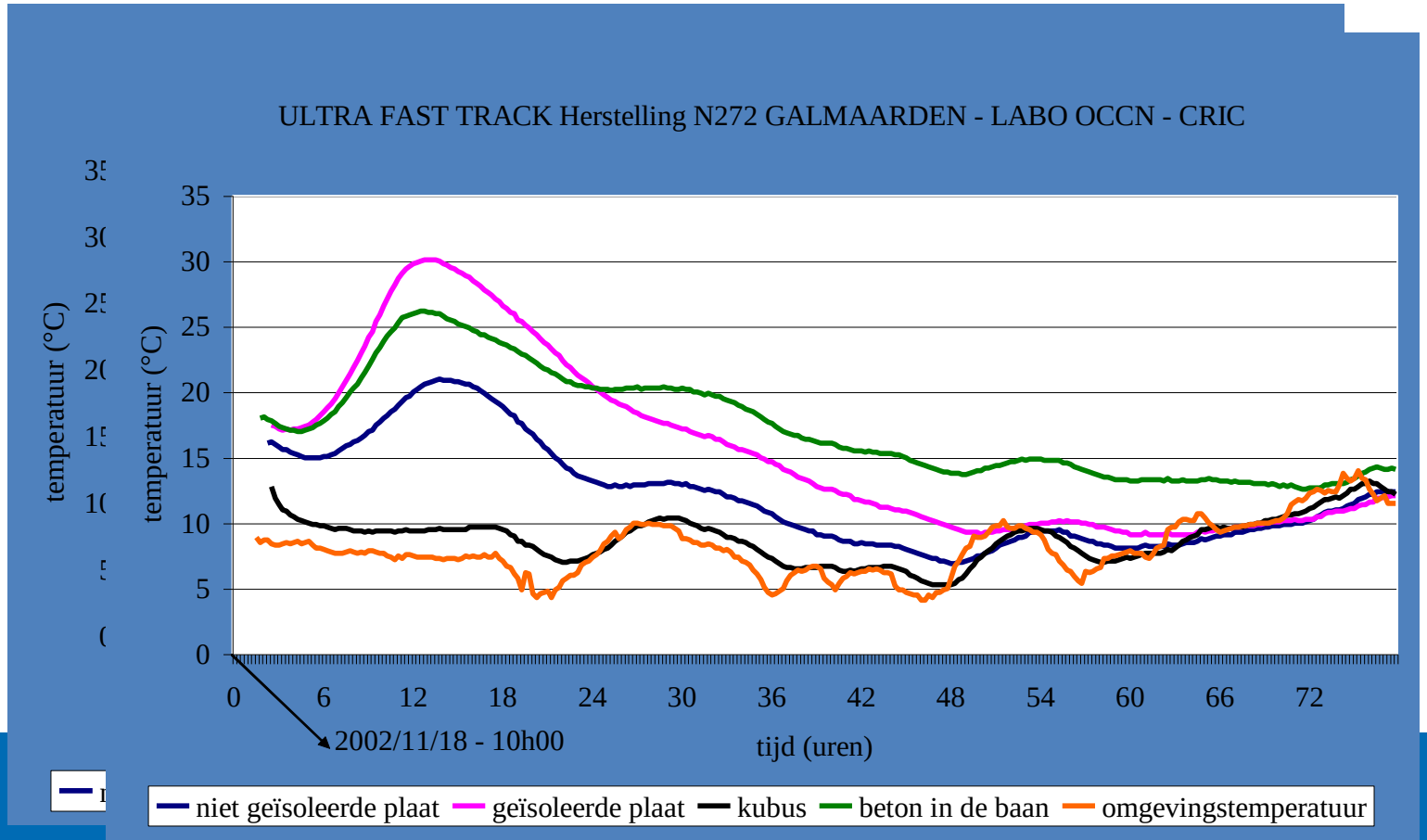

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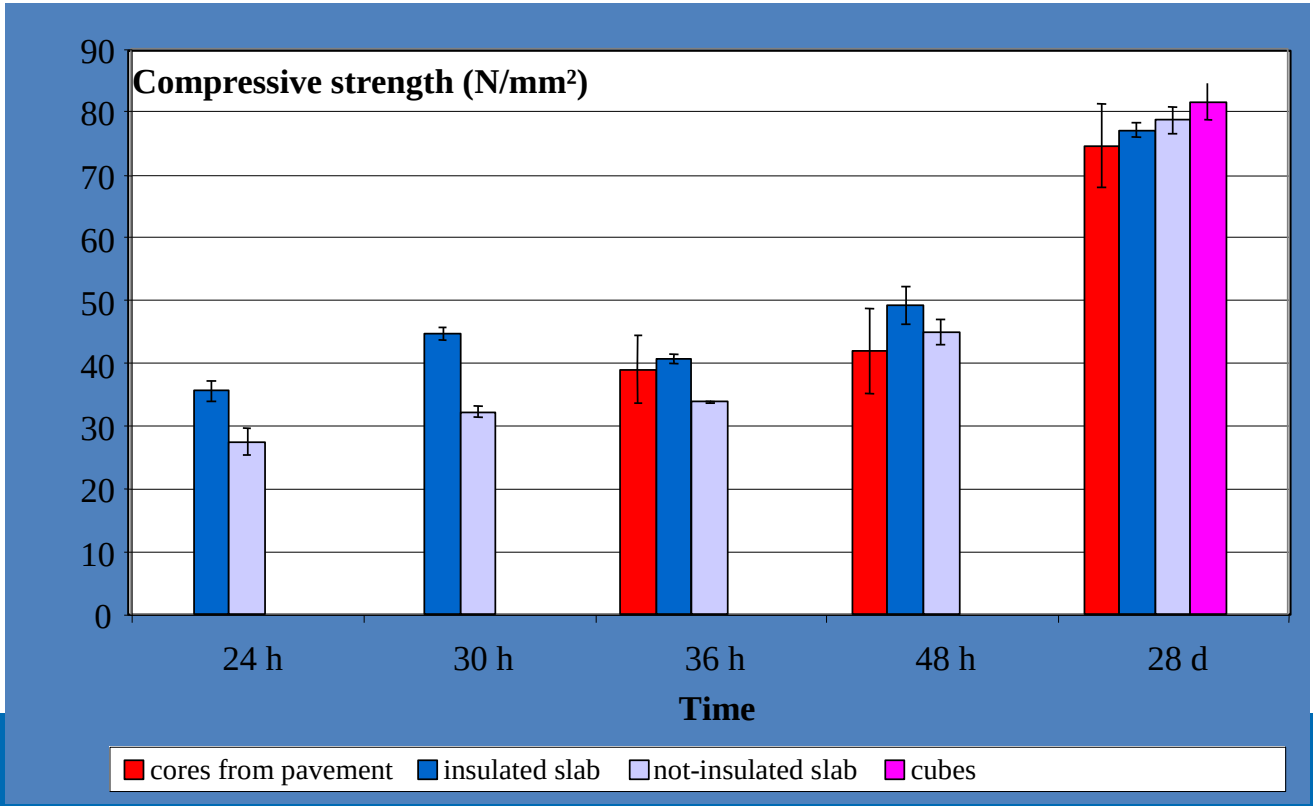

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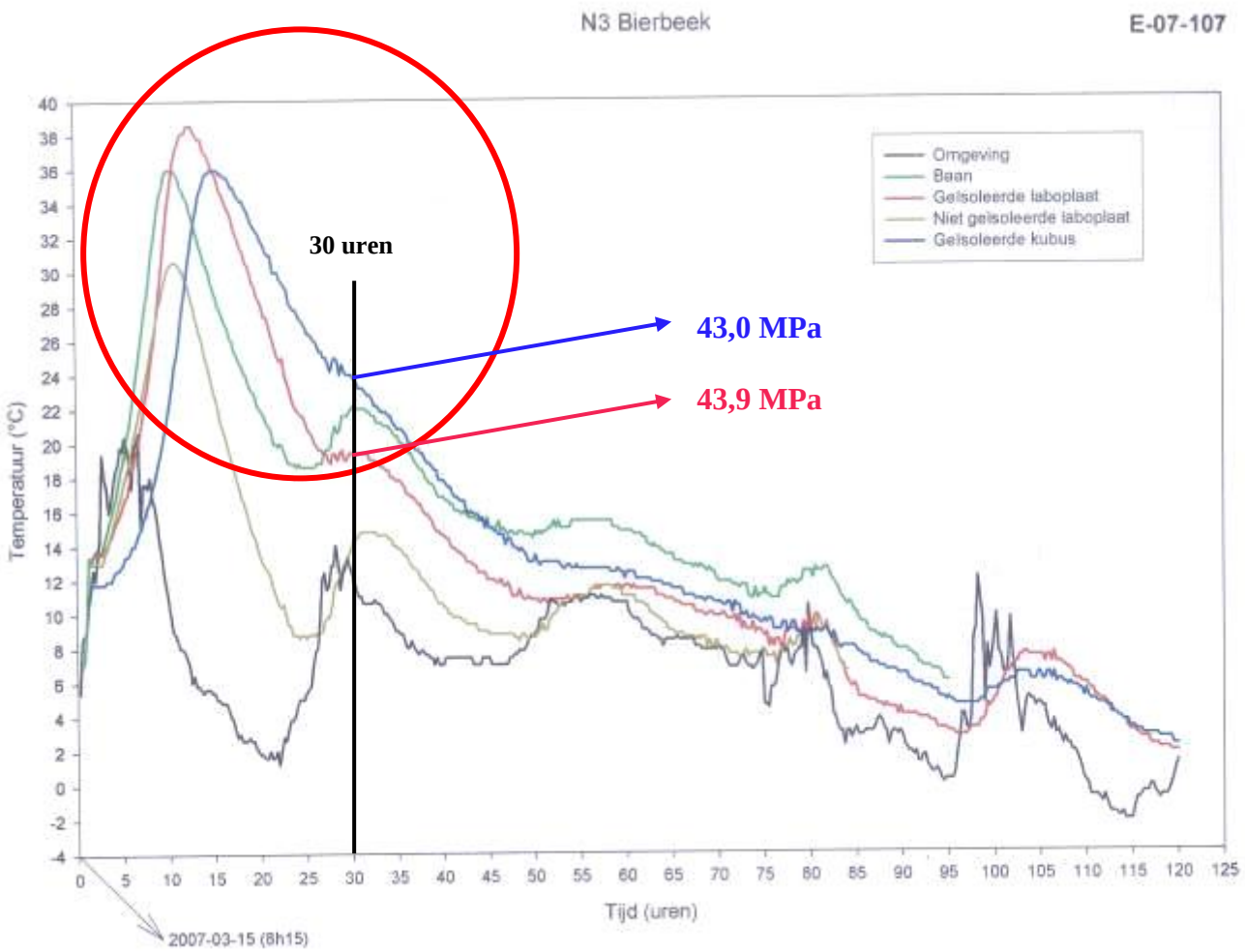

Evolution of sensors

- New sensors have appeared on the market
  - Maturity measurements
    - Determining time of demoulding
    - Temperature control in mass concrete...

Evolution of sensors

- New sensors have appeared on the market
  - Maturity measurements
  - Wireless – 24/7 monitoring

SmartRock2

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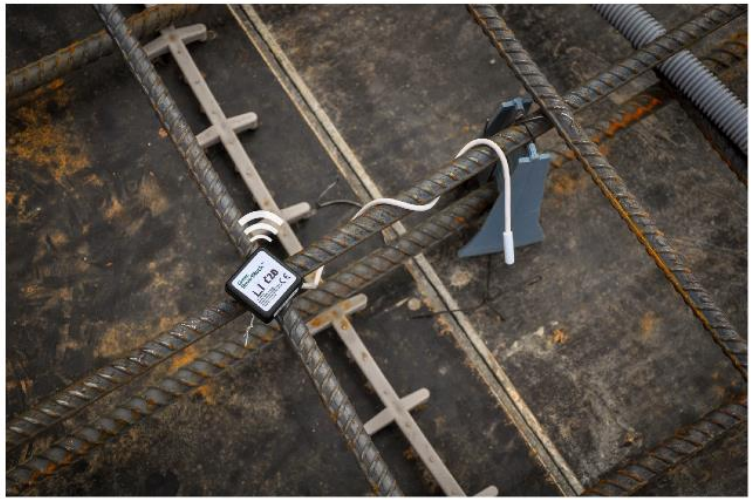
Monitoring Concrete Temperature with Wireless Sensors

by RYAN CUCHERAN July 25, 2019



Evolution of sensors

- New sensors have appeared on the market
  - Moisture measurement

Humidity sensor

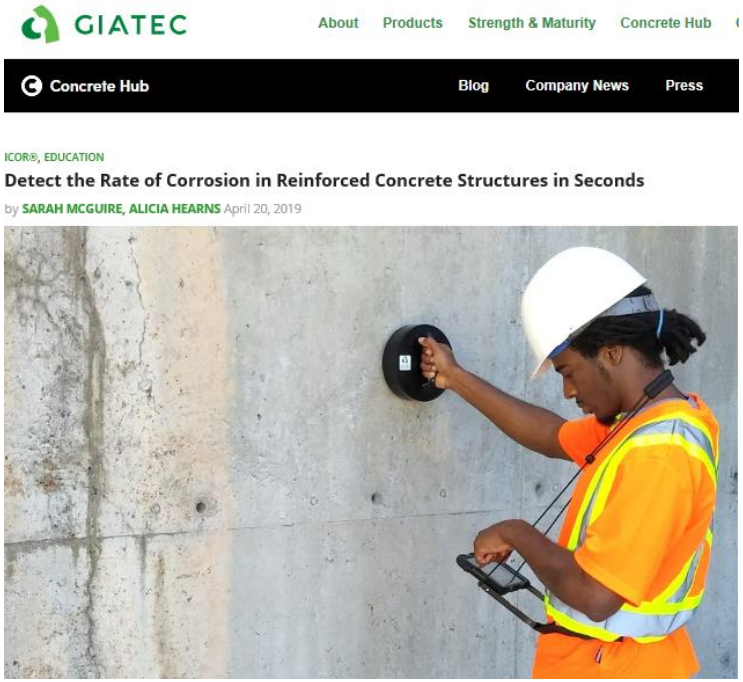
Mode of action:
- Energy supply from the RFID field of the reading device
- Statement of as-is state to the differences in detection
- Measurement electrolytic resistance
- Mesurement of ground temperature

Material:
- Circular stainless steel band to check humidity
- Artificial resin and fiber concrete
- Standard-box diameter 91 mm
- Standard-box height 26 mm
- Attachment at reinforcement with sensor housing and integrated handling-wire

Optional:
- Special construction form made of fibre cement
- Special flexible construction (separation of communication and sensor part)
- Remote enquiry possible with I-Net

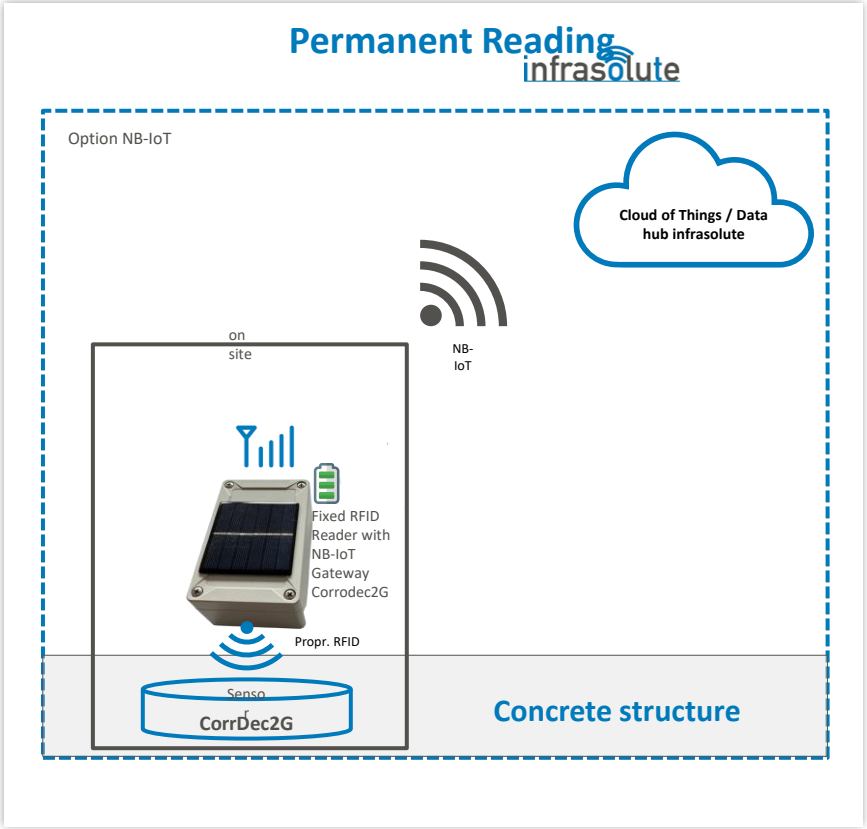
Evolution of sensors

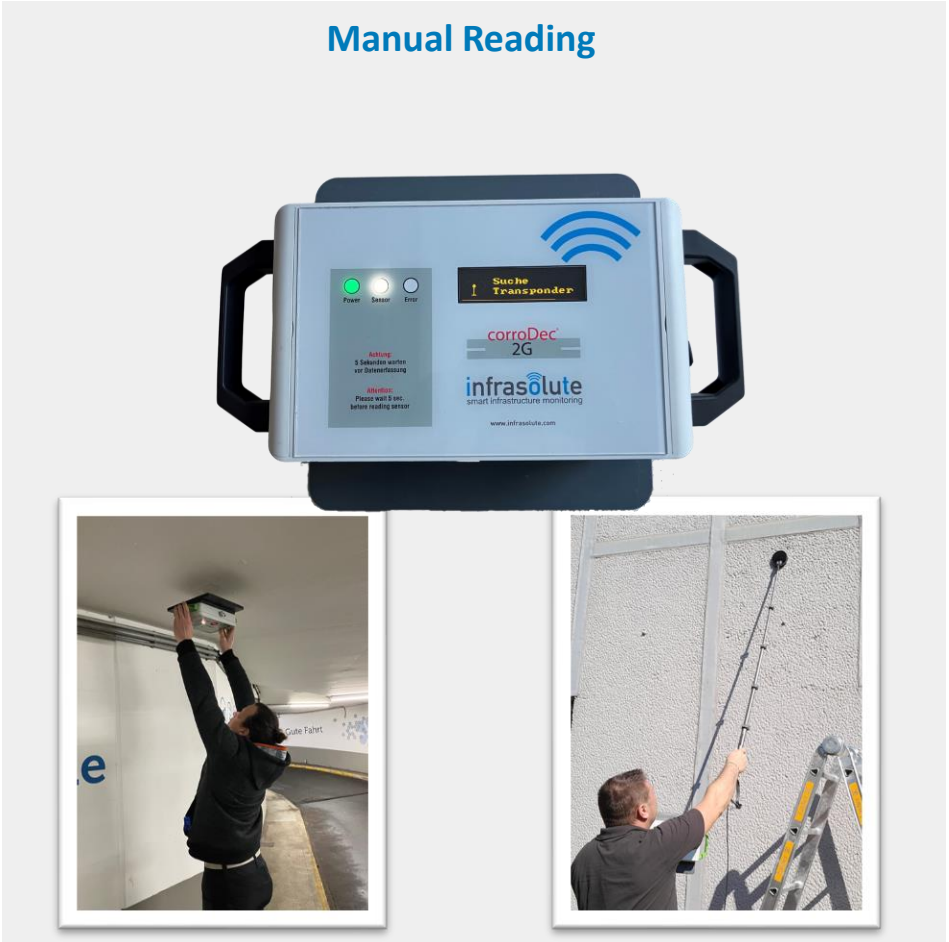
- New sensors have appeared on the market
  - Corrosion detection



Evolution of sensors

- Reading of the sensors





Evolution of sensors

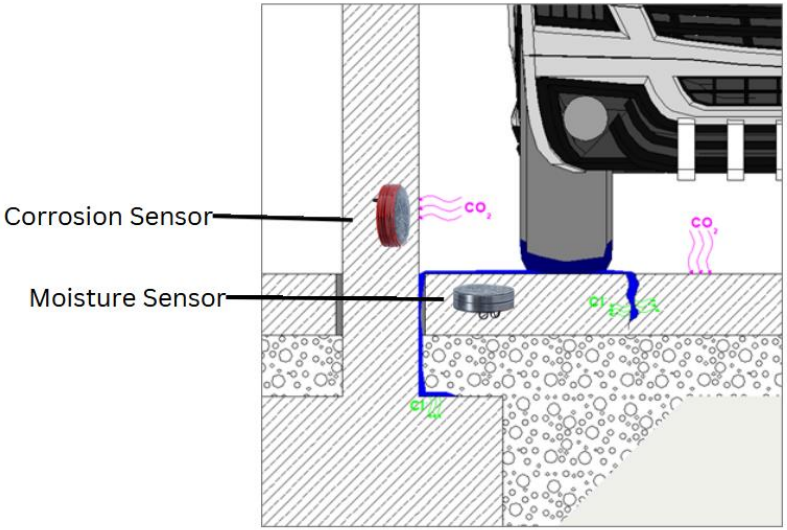
- Case of a parking garage in Germany

Original construction: 1970

Renovation: 2018

Objectives: Monitoring of remaining chlorides in the concrete
Short-term assessment of the success of the repair measure Permanent monitoring of moisture in the concrete

One corrosion sensor and one moisture sensor each



Evolution of sensors

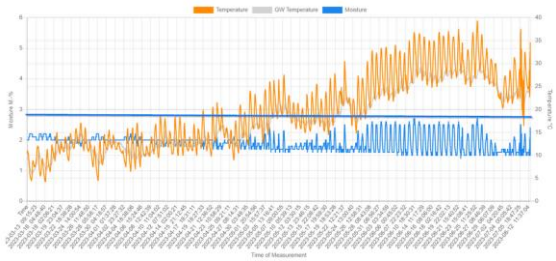
- Case of a parking garage in Germany

Installation: Core drilling

Diameter: 10 cm
Depth: 4 cm

Data read out: both manual and automatic

the sensors at the most critical locations were permanently monitored with a gateway (using a long-term battery)



all other sensors were manually read using a handheld device during the semi-annual physical inspection

Evolution of sensors

- Development of wireless micro-sensors
- « Health monitoring » of temperature and humidity in concrete
  - Ref: Shuo Yang, Keyan Shen, Halil Ceylan, Sunghwan Kim, et al.. "Integration of a prototype wireless communication system with micro-electromechanical temperature and humidity sensor for concrete pavement health monitoring" *Cogent Engineering* Vol. 2 Iss. 1 (2015) p. 1014278

EmbedSense® Wireless Sensor

Wireless sensor and data acquisition system.

Features and Benefits

- Small size is ideally suited for embedded applications
- No batteries to maintain, hence nodes can operate for the life of the structure or machine
- Wide operating temperature from -40 C to +125 C
- 30 Hz sample rate
- Configuration available for high inertial loads, up to 50,000 g
- Low cost
- Requires no physical connection
- Communicates through non-conductive materials

Maturity of concrete

- Weighted maturity curve
  - Combined influence of time and temperature on the strength development of concrete
  - “Weighted” : influence of binder

$$M_W = \sum t \times T \times C^n$$

where:

M_w is the weighted maturity (°C·h or °C·days)

t is the age/time of concrete (h or days)

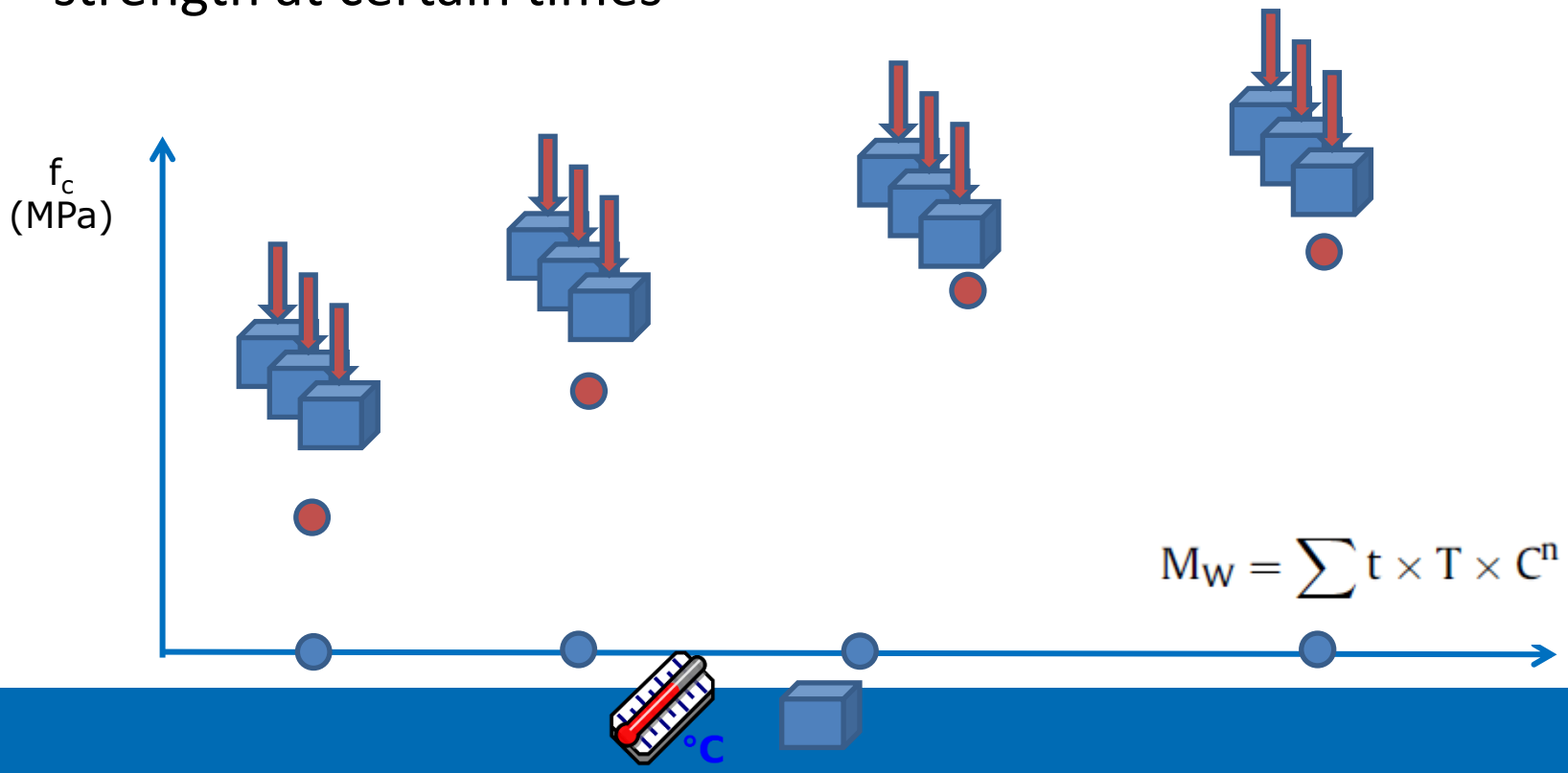
T is the average concrete temperature during time interval Δt (°C)

n is a temperature dependent parameter

C is a cement specific constant for which the strength maturity curves for isothermal strength tests at 20 and 65 °C coincide, C – cement specific value.

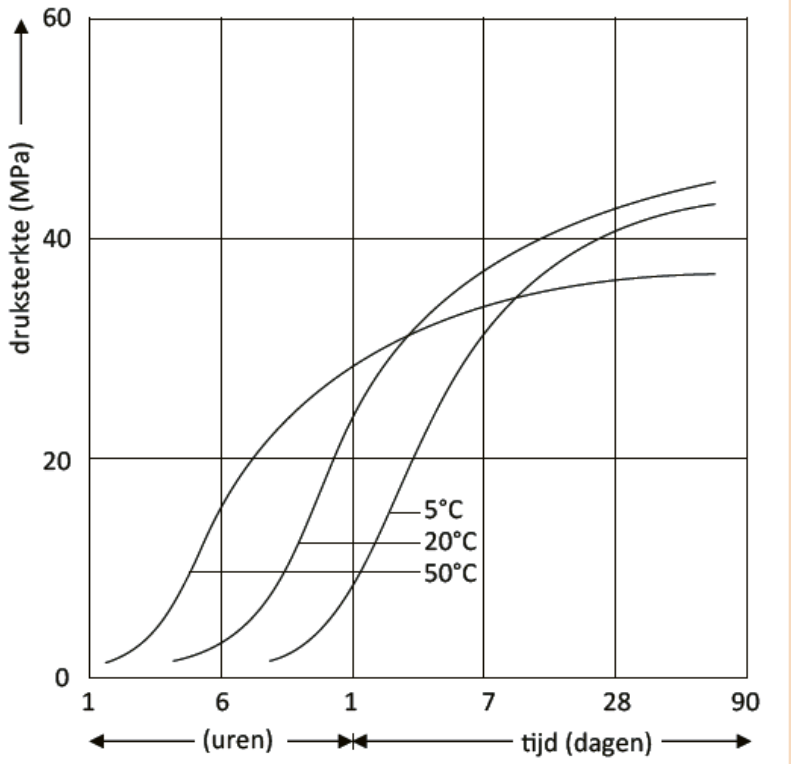
Maturity of concrete

- Calibration of the concrete mixture = establishing a calibration curve
- Measuring time and temperature + determining compressive strength at certain times



Maturity of concrete

- Influence of temperature on strength development



6 Schematische sterkteontwikkeling bij verschillende verhardingstemperaturen

Maturity of concrete

- Applications
  - During execution
    - Determining time of saw-cutting of contraction joints
      - "not too early" because of pulling out stones at the edge of the sawcut
      - "not too late" because of risk of shrinkage cracking
    - Determining time of washing out of the surface (exposed aggregate concrete)
      - Important for final texture depth

Maturity of concrete

- Application
  - On entry into service
    - Checking compressive strength of the concrete: on drill cores from the pavement

    - E.g.: …heavy traffic allowed when the average compressive strength on 3 cores reaches 40 MPa…

Maturity of concrete

- Application
  - On entry into service
    - Checking compressive strength of the concrete: on drill cores from the pavement
    - For rapid-hardening concrete: on insulated cores, stored at worksite conditions
    - E.g. …opening to traffic … the average compressive strength of 3 cubes is at least 35 MPa…

Maturity of concrete

- Establishing calibration curves
- Insert sensors during concreting

- Recording time and temperature
- Determination of maturity and concrete strength

- Reporting
- Notification on smartphone

Concluding remarks

- Through the use of sensors in a concrete pavement, and the weighted maturity method, it is possible to determine the best moment for:
  - Saw-cutting
  - Aggregate exposure
  - Putting in service

  with no need to drill cores in the pavement.

- Other interesting options:
  - Monitoring durability by measuring moisture content, corrosion,…

- More applications please!

Concluding remarks

- Today, only few applications of sensors in concrete road construction can be observed
- Why?
  - Too expensive?
  - Only discrete and no continuous measurement?
  - We still need to drill cores for thickness control?
  - No sense of need?
  - We always managed to do it without?

Concluding remarks

- Possibly, future R&D will bring us the answer?
  - Cheap, continous measuring systems which enable to give an overall image of the concrete quality
  - Combined techniques eliminating all need for cores
  - Time-saving and cost-saving creating significant advantage over competitors
  - Enhanced quality control and assurance, an effective tool for road agencies

- What brings that future?
  - Drones
  - AI
  - …??


Thank you for your kind attention