INTEGRAL BRIDGE DESIGN IN SOUTH AFRICA

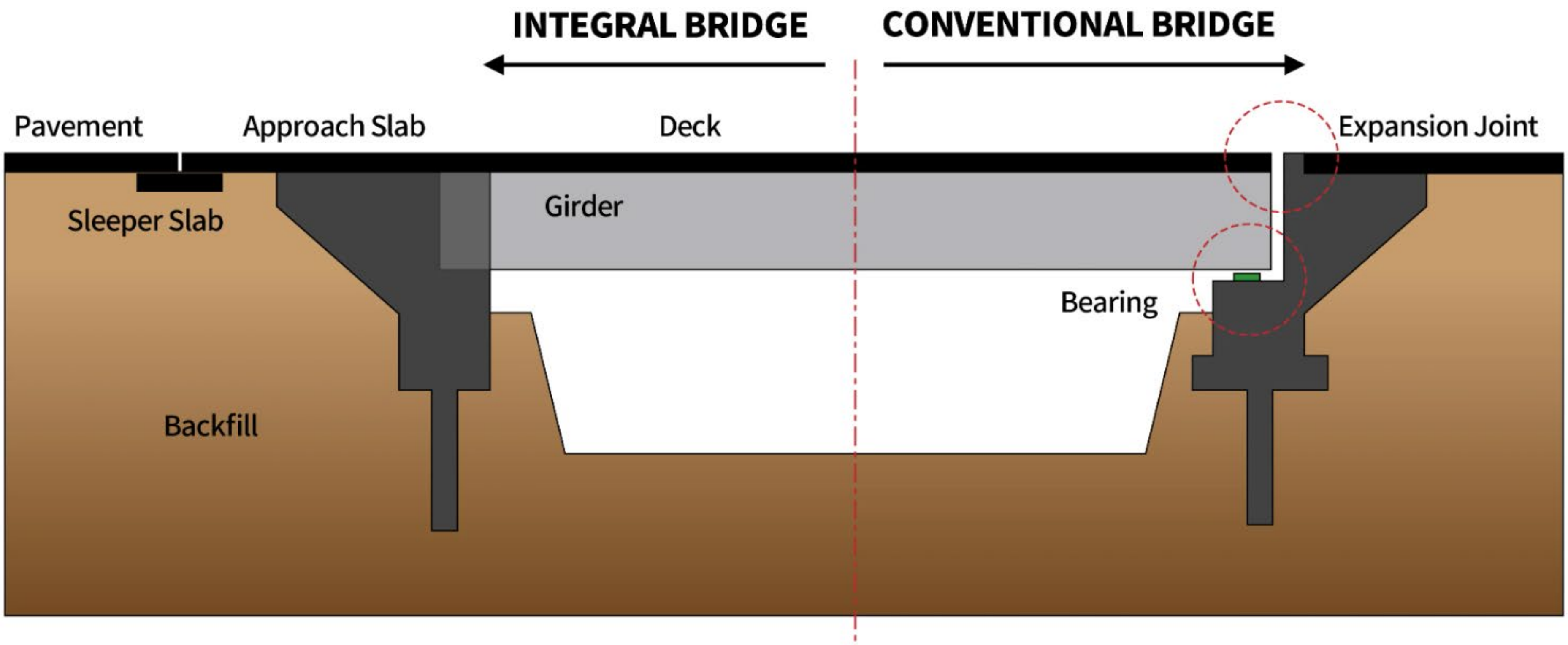
Sarah Skorpen

PhD, PrEng, CEng, MIStructE

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology
Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

INTEGRAL BRIDGES



Integral bridges vs conventional jointed bridge (Midas Civil)

UK PD6694-1-2011 AND A1-2020

This document covers geotechnical consideration for bridge design in the UK

9.2 Methods of analysis

9.2.1 Limit equilibrium methods

The limit equilibrium analysis methods described in 9.4.3 and 9.4.4 are applicable to abutments that satisfy the following conditions

a) the characteristic thermal movement of the end of the deck does not exceed 40 mm;

b) the skew does not exceed 30°; and

c) the depth of soil affected by the abutment movement can be identified without recourse to a soil–structure interaction analysis.

The depth of soil affected by the abutment movement for the following types of abutments can be identified without recourse to a soil–structure interaction analysis:

1) abutments founded on spread footings (9.4.3);

2) end screen abutments (9.4.4); and

3) abutments seated on pile caps consisting of more than one row of piles, provided that the sway at pile cap level is sufficiently small for at rest pressure to be considered as acting at pile cap level (9.4.3).

INTEGRAL BRIDGE DESIGN IN SA

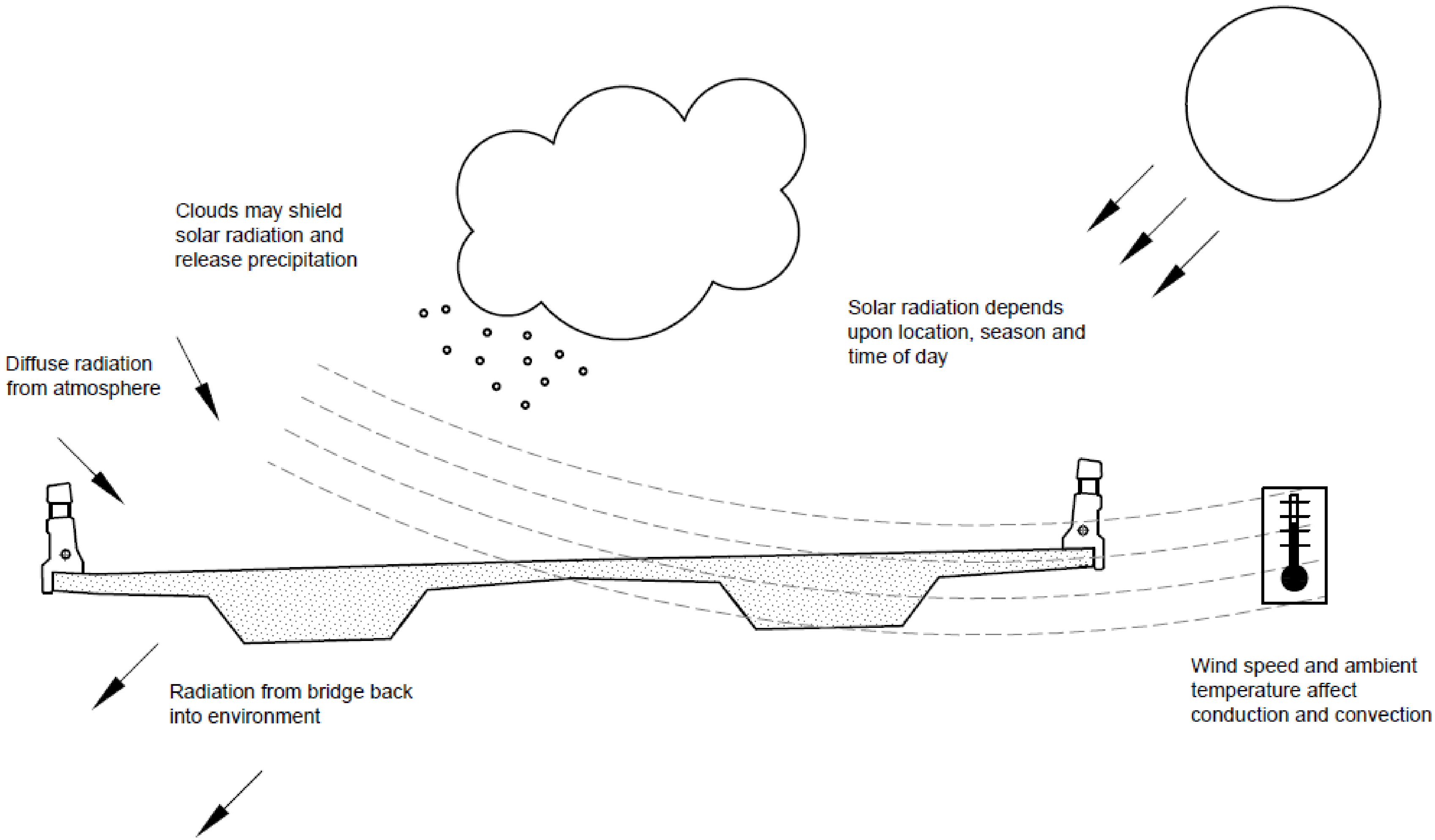
What additional factors do we need to consider for integral bridge design?

- Environmental conditions
- Deck effective temperature
- Concrete shrinkage
- Earth pressure and backfill properties
- Construction sequence
- Maximum IAB length

How are we trying to answer these questions?

- Van Zylspruit bridge monitoring – University of Pretoria and SANRAL
- SANRAL Research Project 7a2 – Integral Bridges in South Africa

BRIDGE ENVIRONMENTAL CONDITIONS

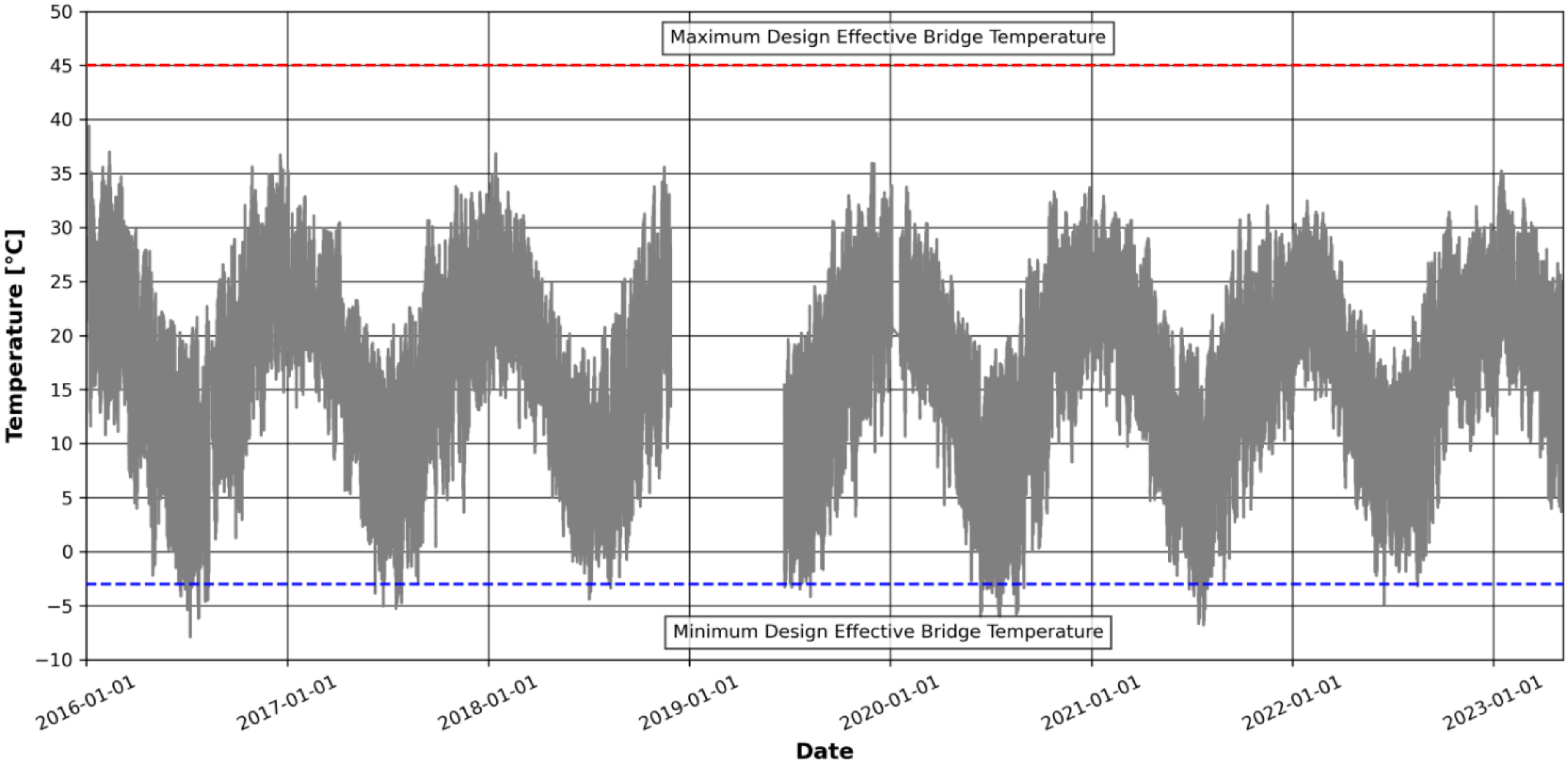


Environmental Actions on Bridges (Tindal et al., 1998)

VAN ZYLSPRUIT BRIDGE

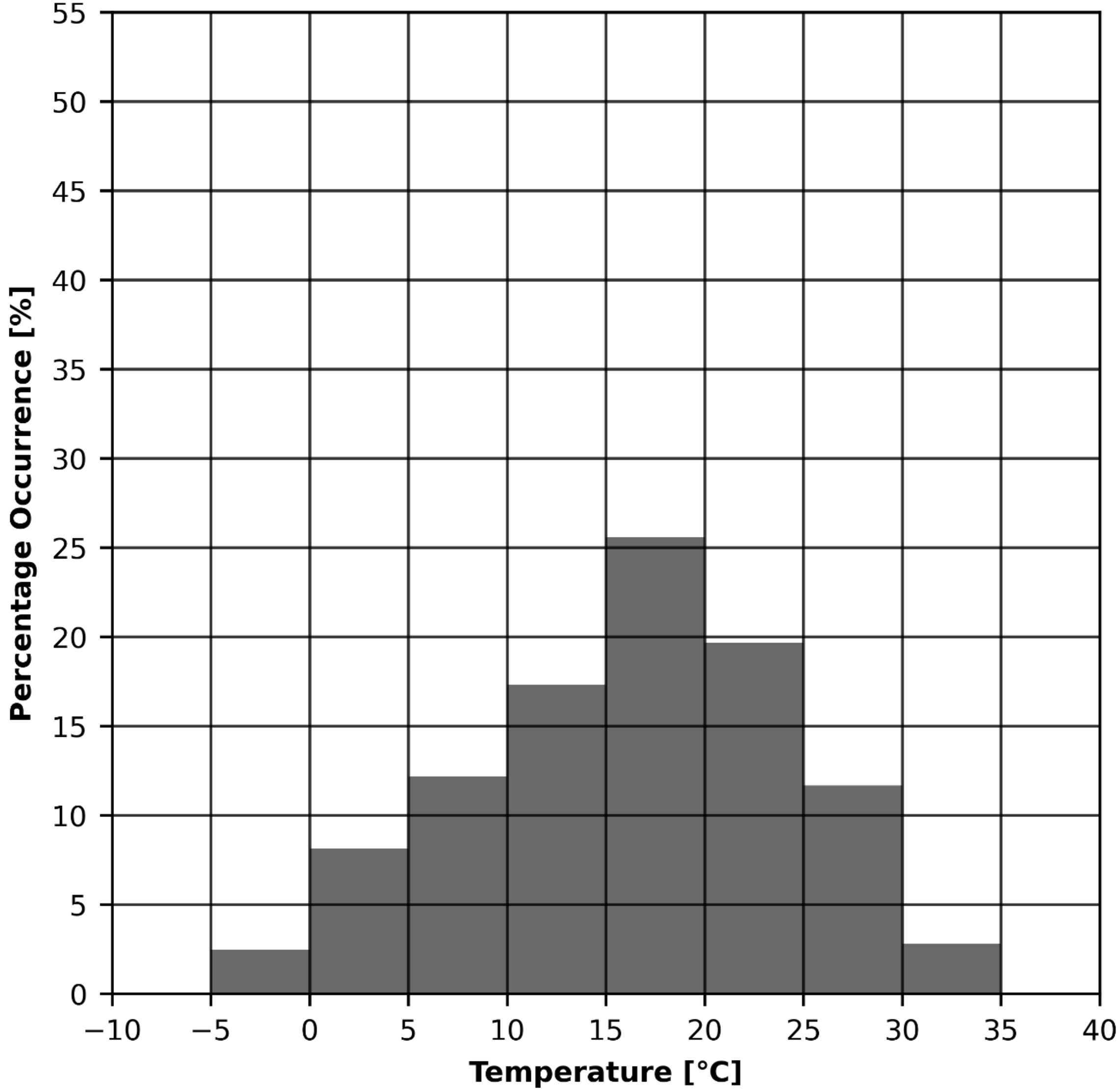
AMBIENT SHADE TEMPERATURE

Measured ambient shade temperature: +40°C to -8°C



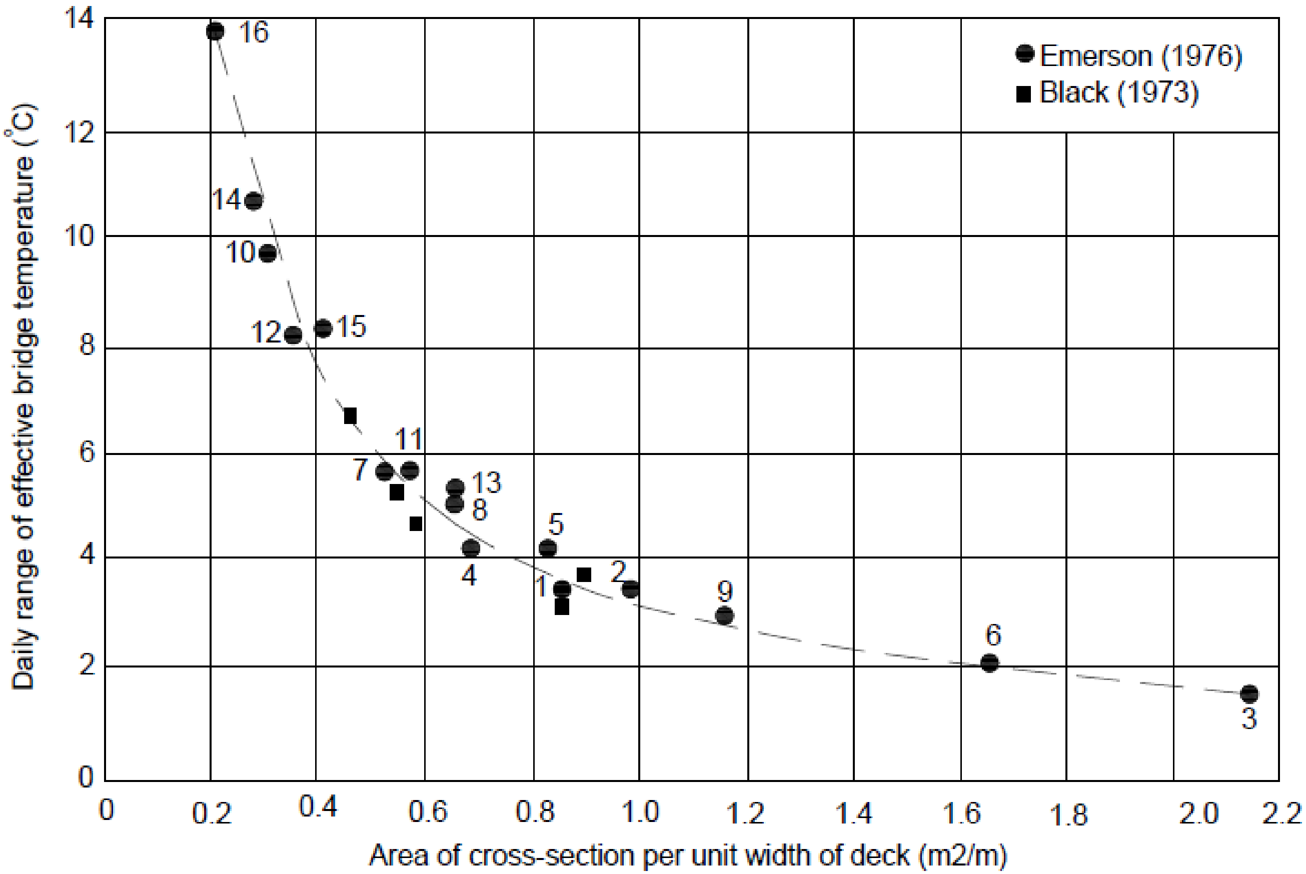
Measured ambient shade temperature at Van Zylspruit, 2016 to 2023

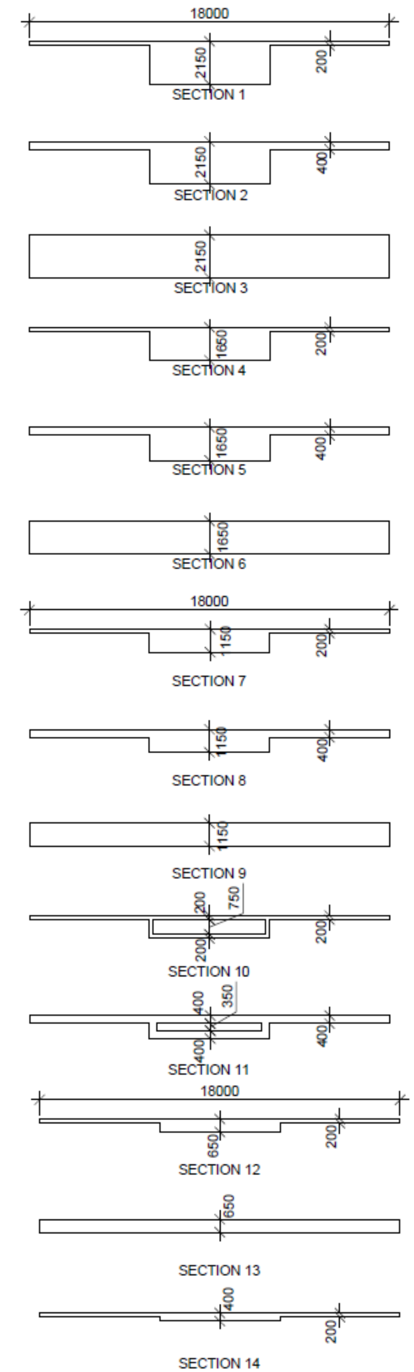
AMBIENT SHADE TEMPERATURE



Percentage occurrence of the ambient shade temperature at Van Zylspruit, 2016 to 2023

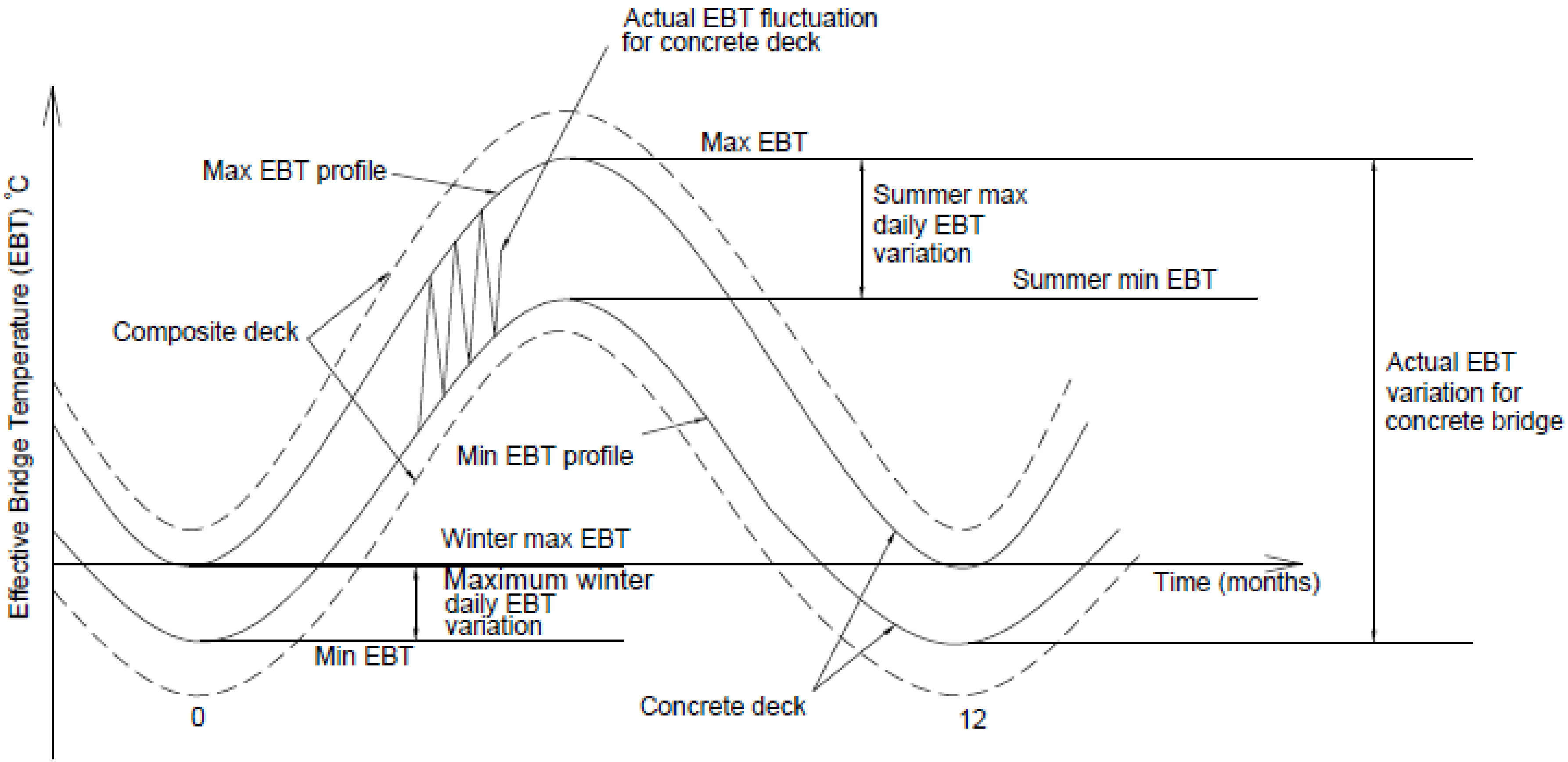
EFFECTIVE DECK TEMPERATURE





Effect of area of cross section per unit width of deck on daily range of effective bridge temperature (Black et al., 1979).

EFFECTIVE DECK TEMPERATURE

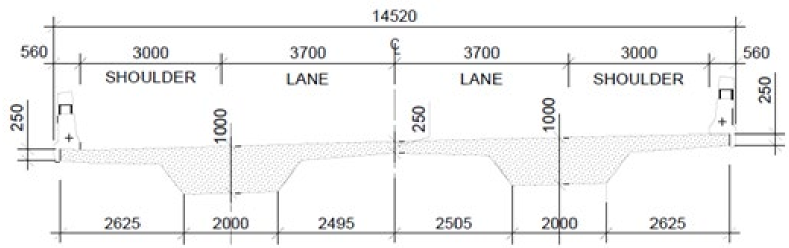


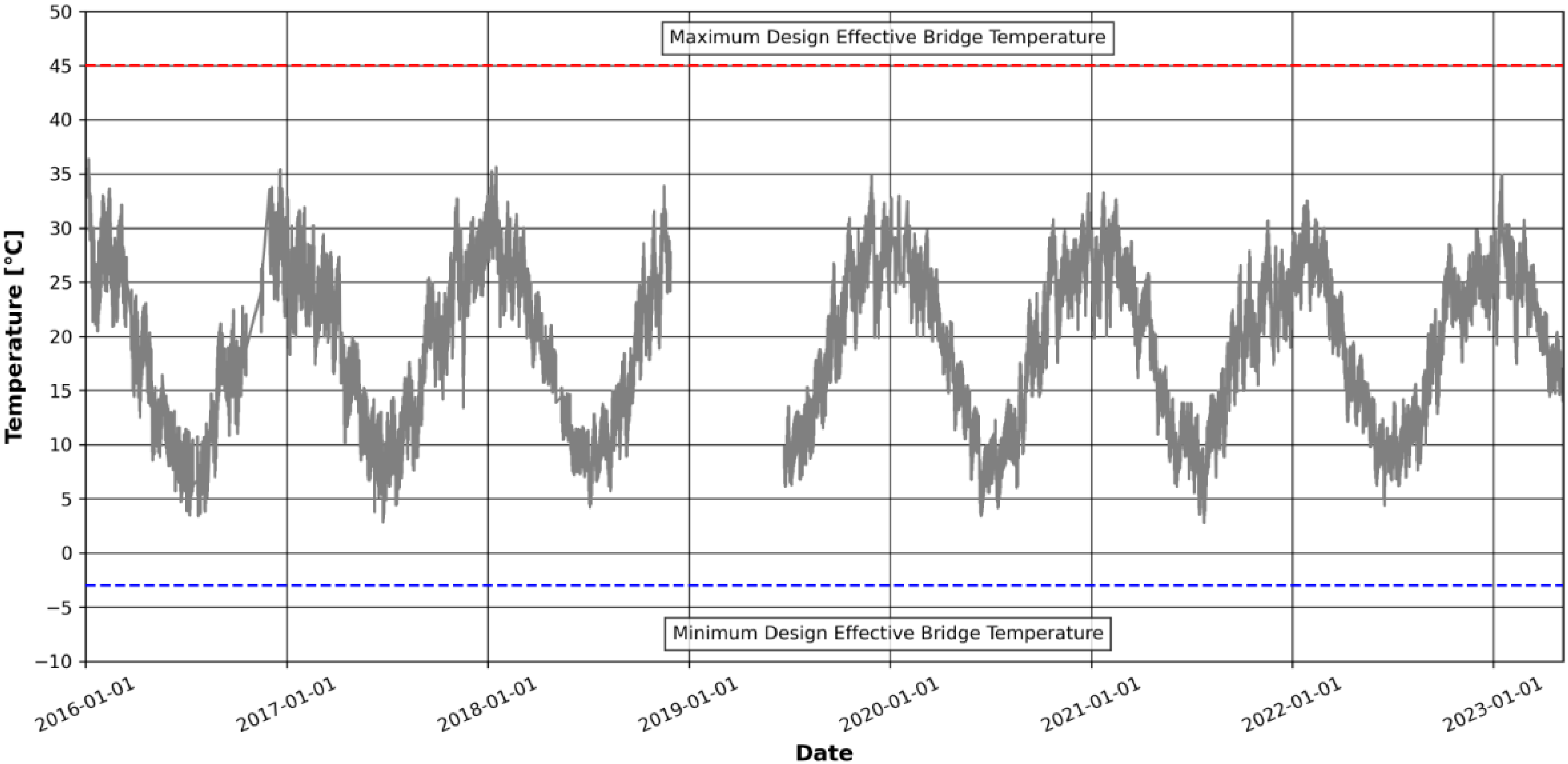
Concrete deck Effective Bridge Temperatures (EBT) showing daily and seasonal variation compared with composite deck effective bridge temperatures (England et al., 2001)

EFFECTIVE DECK TEMPERATURE

Measured Effective bridge deck temperature:
Max: 35.33°C and Min: 3.24°C

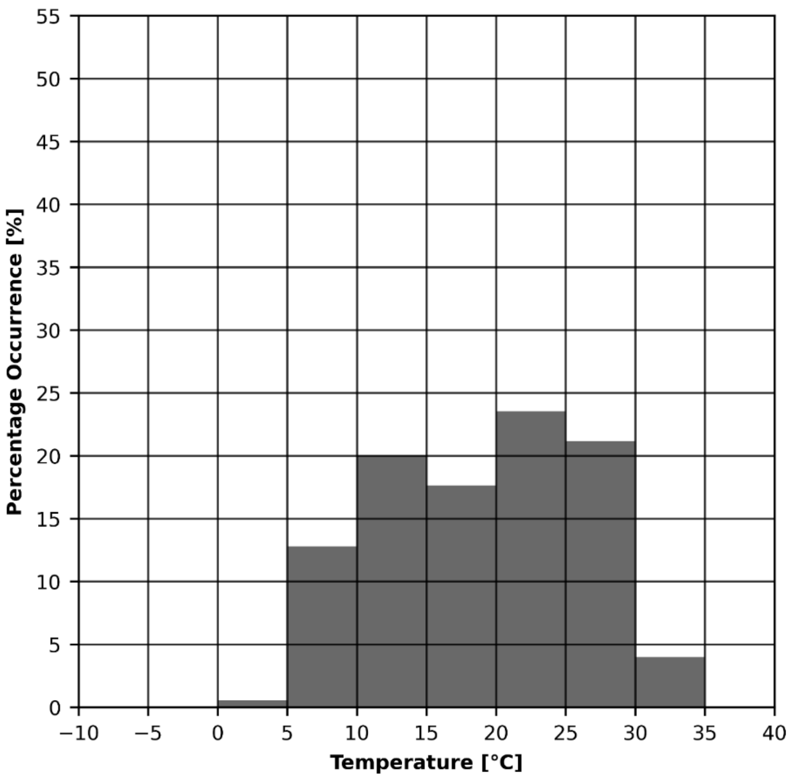
Design Effective bridge deck temperature:
Max: 45°C and Min: -3.°C



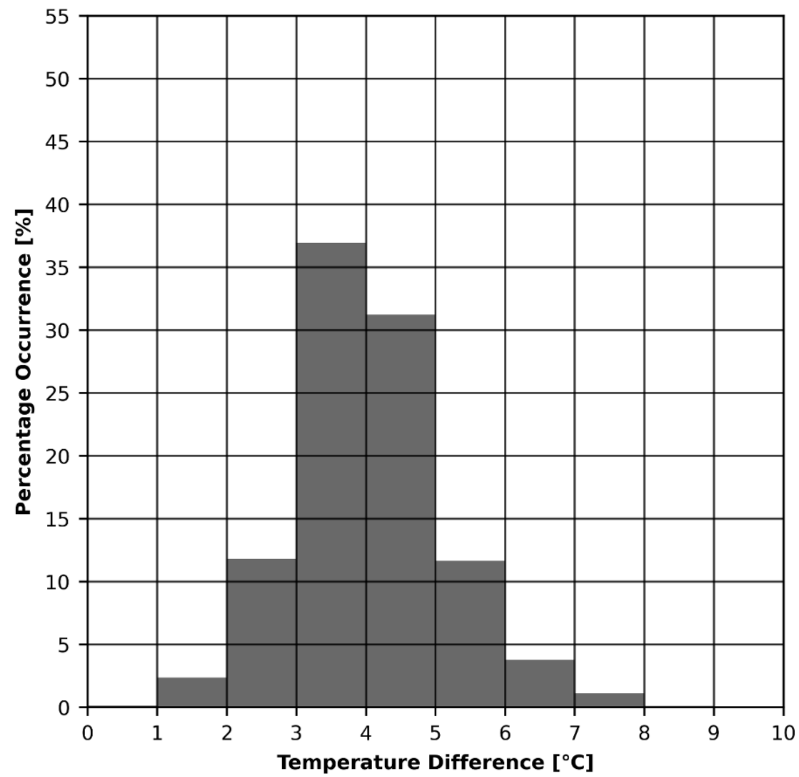


Effective deck temperature of the Van Zylspruit deck, 2016 to 2023

EFFECTIVE DECK TEMPERATURE



Percentage occurrence of effective deck temperature at Van Zylspruit, 2016 to 2023

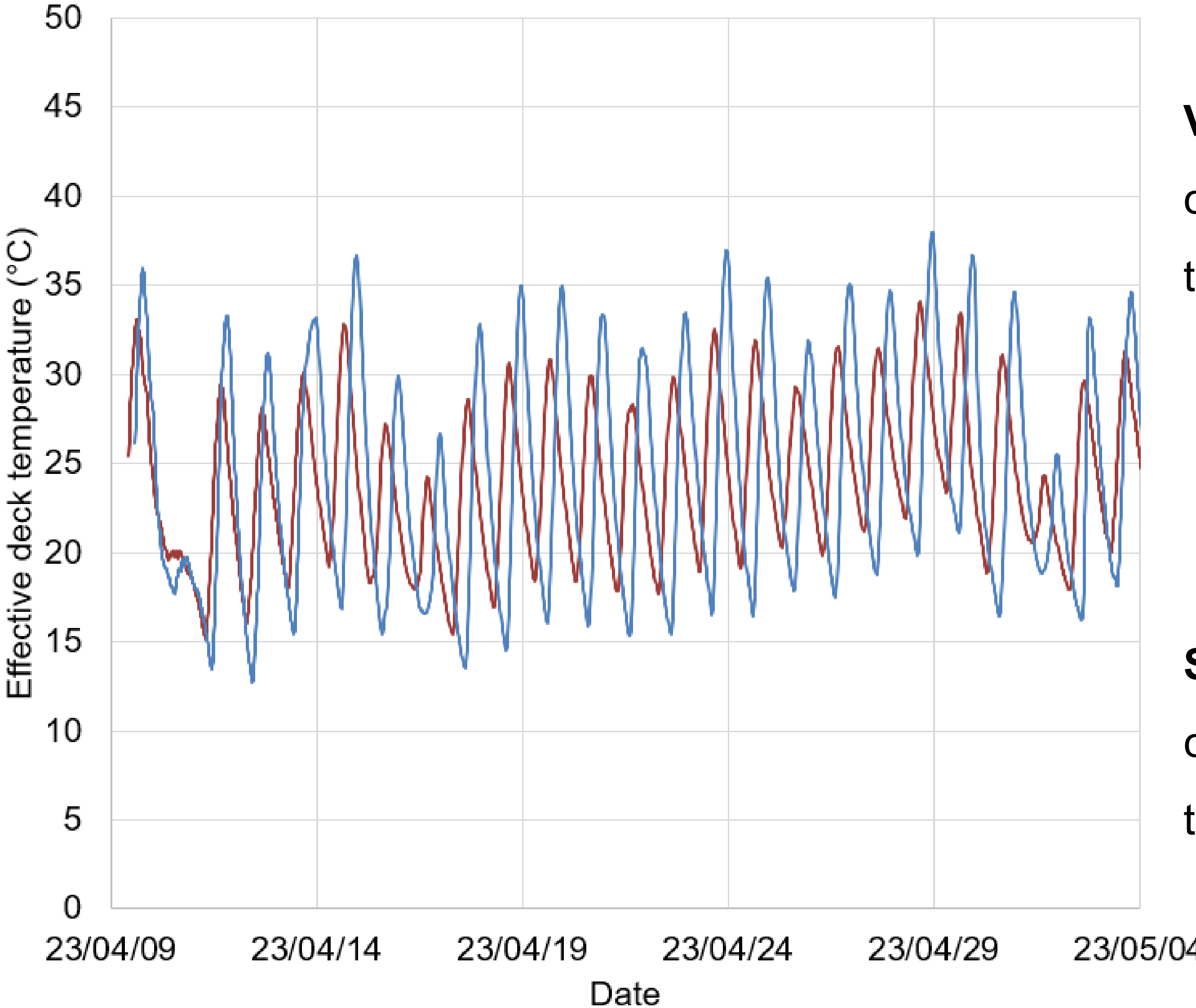


Percentage occurrence of daily change in effective deck temperature at Van Zylspruit, 2016 to 2023

EFFECTIVE DECK TEMPERATURE

Different cross sections (Kleynhans, 2023)

EFFECTIVE DECK TEMPERATURE - APRIL

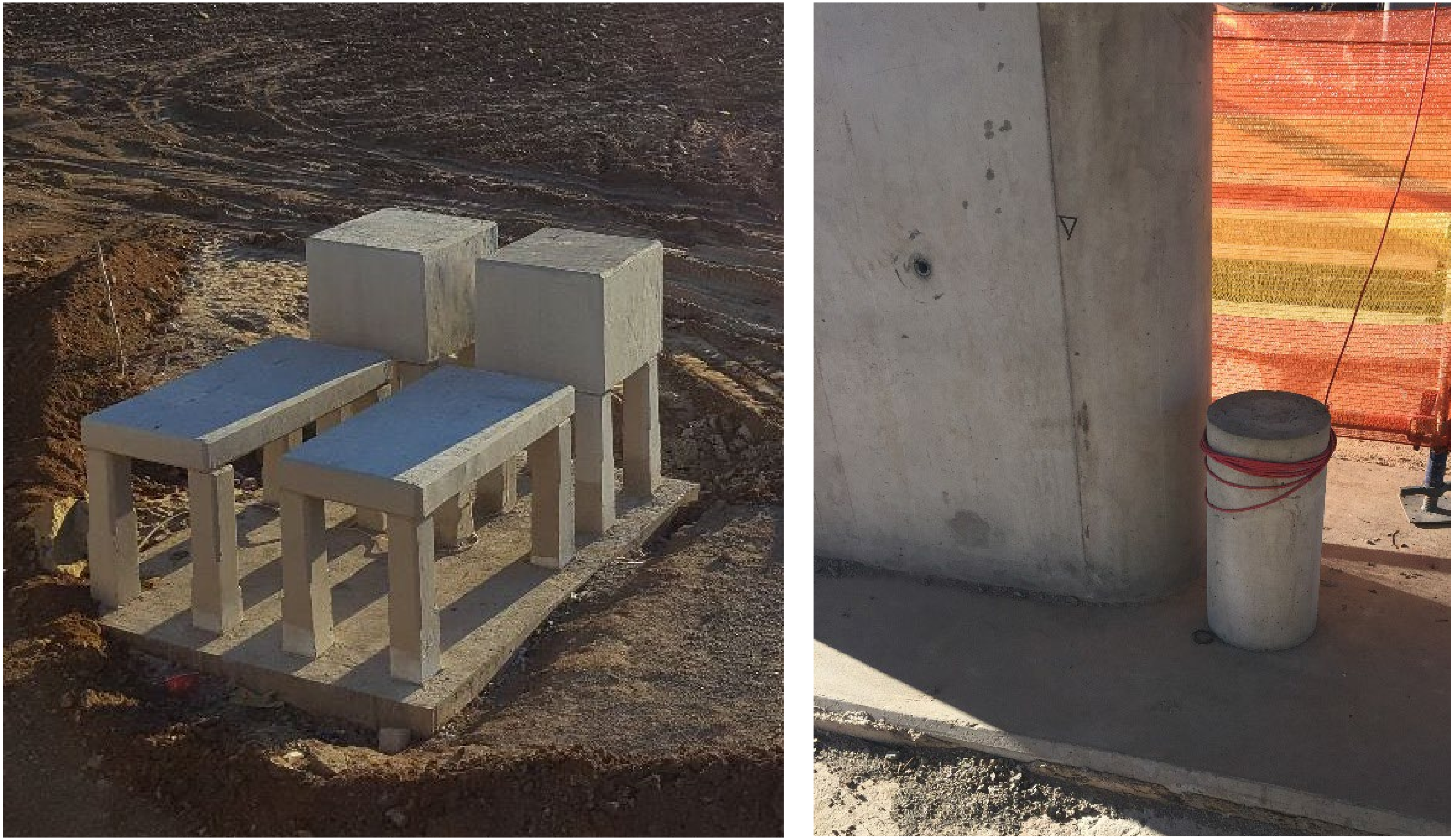


Voided deck daily change in effective temperature: ±21.2°C

Solid deck daily change in effective temperature: ±13.3°C

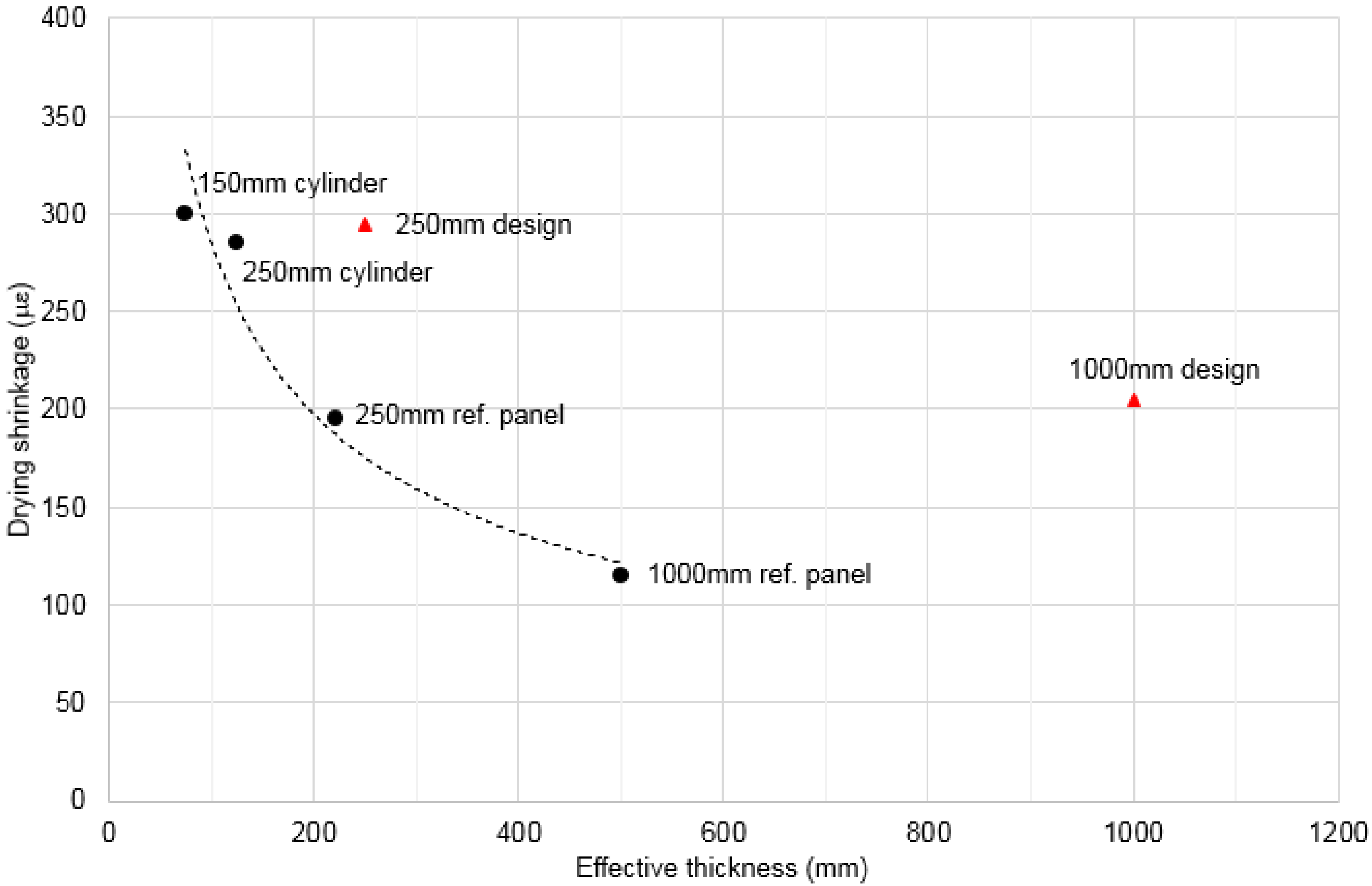
Effective deck temperature (Kleynhans, 2023)

CONCRETE SHRINKAGE



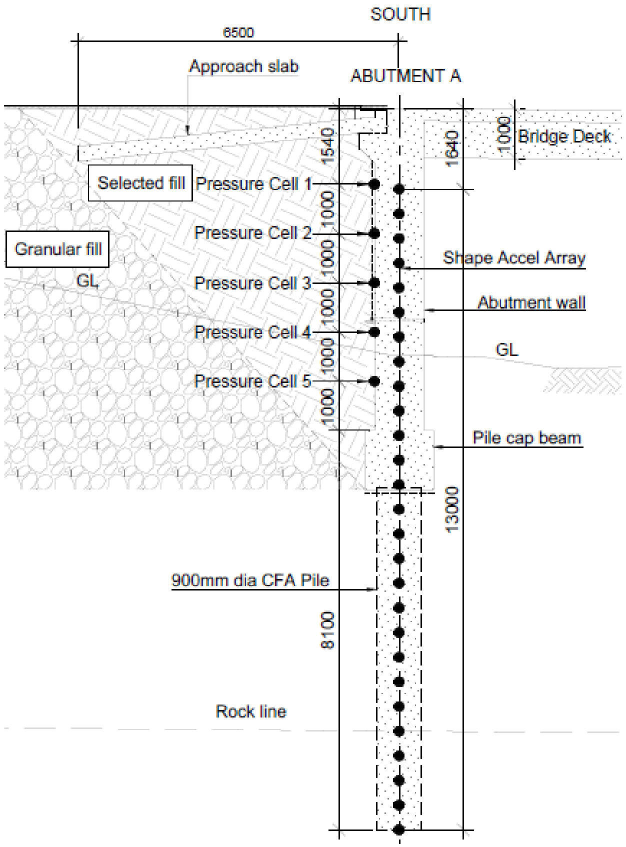
Shrinkage reference structures (Skorpen, 2020)

CONCRETE SHRINKAGE

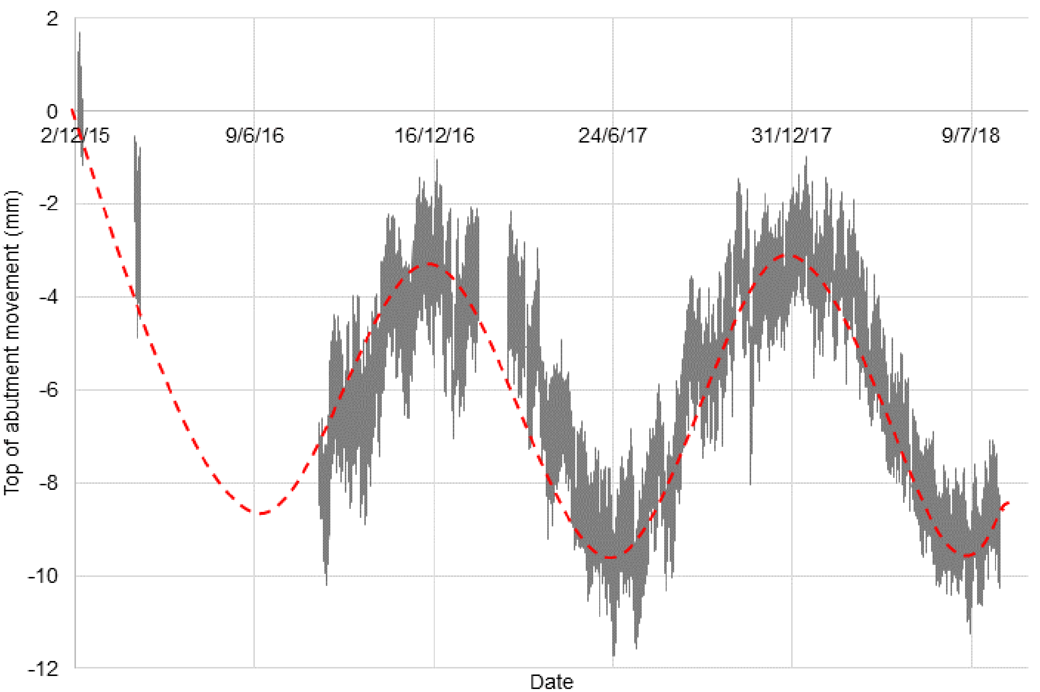


Measured drying shrinkage compared with design drying shrinkage (Skorpen, 2020)

SHRINKAGE - ABUTMENT MOVEMENT



Section through the abutment wall showing the pressure cell and SAA positions



Top of North abutment movement from end of December 2015 to August 2018.

Measured Shrinkage displacement of 6mm – approximately 130$\mu\varepsilon$ on 45m

UK PD6694-1-2011 AND A1-2020

This document covers geotechnical consideration for bridge design in the UK

9.10.1 Backfill material

The design methods given in this document assume that the backfill material for integral bridges is free draining granular material with properties and grading conforming to Classes 6N or 6P, specified, installed and compacted in accordance with the *MCHW* [7] or as given in the project specification

It is important that the backfill is neither too weak nor too strong. For example, an underestimate of φ' could underestimate earth pressures during thermal expansion, whilst an overestimate of φ' could overestimate the abutment's resistance to longitudinal braking forces. The selection of backfill material for integral bridges is typically a compromise between stiffness and strength. The design should be based on a range of soil strengths and the upper (superior characteristic) and lower (inferior characteristic) values assumed should be credible for materials likely to be economically available for the proposed structure and be stated in the contract, together with test procedures and acceptance criteria.

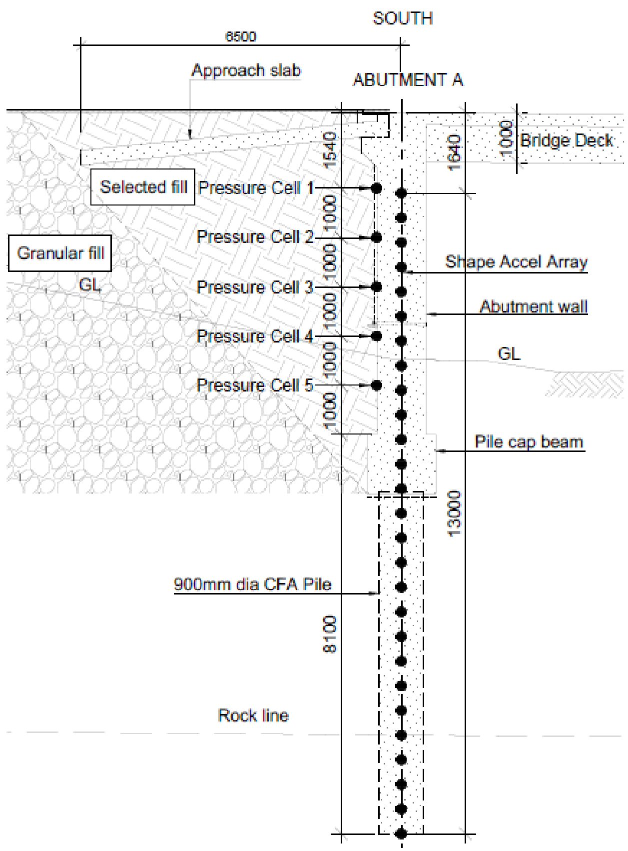
Granular materials comprising compacted rounded particles of uniform grading can have a peak angle of shearing resistance, φ'_{pk}, as low as 35° and may accommodate thermal expansion without high earth pressures. However, such materials typically have low stiffness, making them vulnerable to settlement. Fill of compacted, well-graded hard angular particles can have a peak angle of shearing resistance as high as 55° with very high resistance to thermal expansion.

It is typical for Classes 6N or 6P, specified, installed and compacted in accordance with the *MCHW* [7] to be specified to have peak angles of shearing resistance, φ'_{pk}, within the range of 35° to 45°. The assumed material properties should be recorded in the Approval in Principal (AIP) or other technical approval document.

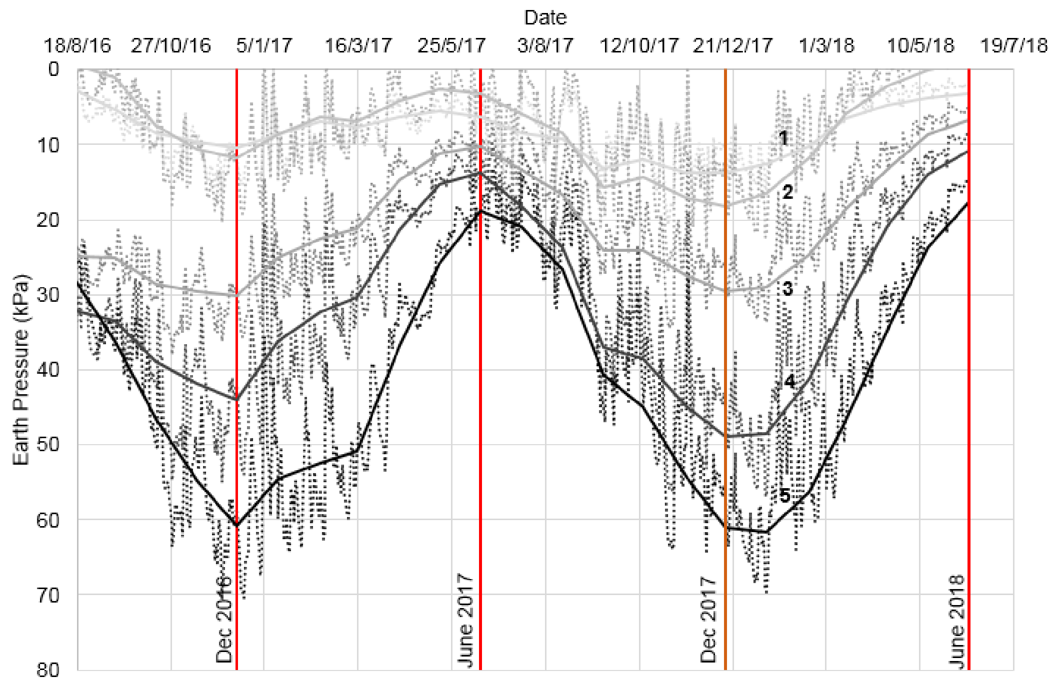
BACKFILL MATERIAL

BACKFILL MATERIAL

ABUTMENT MOVEMENT – PRESSURE



Section through the abutment wall showing the pressure cell and SAA positions



Lateral earth pressure from August 2016 to **July 2023 (update this figure)**

Lateral earth pressure varies between 20kPa and 70kPa at the base of a 6.5m high wall

Active pressure:	33.5kPa
Soil at rest:	52.2kPa
Passive pressure:	455.7kPa

CRACKING AT END OF APPROACH SLAB

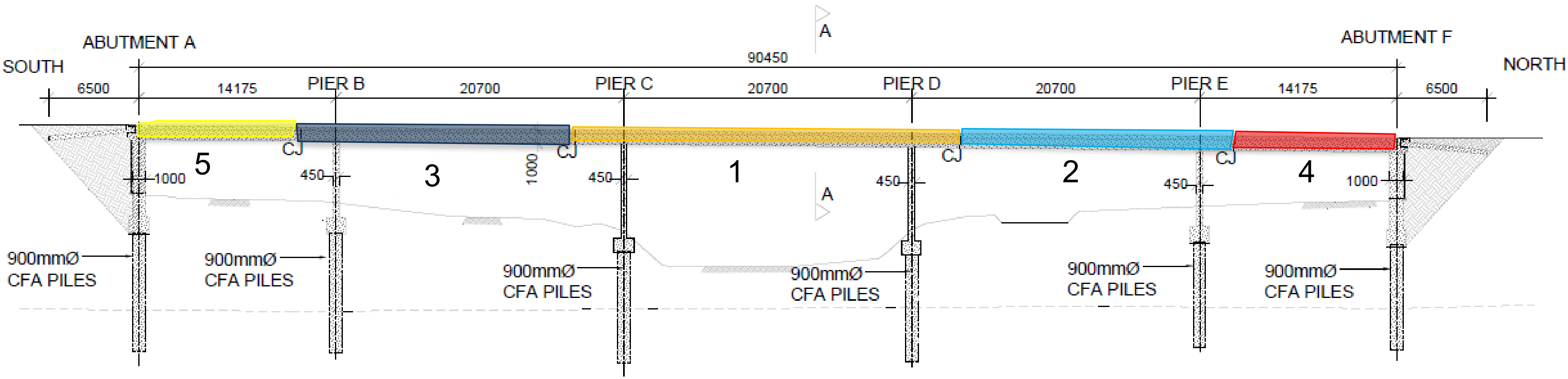
Cold front 30 Jul 2019

6mm crack on Southern side – N lane

North side – no cracks

Measurement and photos taken by Edwin Kruger at Van Zylspruit on 30 July 2019

CONSTRUCTION SEQUENCE



Typical Van Zylspruit Bridge Long section showing construction sequence

CONCLUSIONS

- **Deck effective temperature**
  - This can be much less than you think depending of the type of deck
  - Measured ΔT for a spine beam deck is 32°C (±16°C)
- **Concrete shrinkage**
  - This must be considered
  - Measured drying shrinkage on spine beam is between $100\mu\varepsilon$ and $200\mu\varepsilon$
- **Earth pressure and backfill properties**
  - What material should we be backfilling with?
  - Some cohesion in the fill seems to be beneficial
- **Construction sequence**
  - Abutment displacement is influenced by deck shrinkage
  - We can reduce this by leaving a pour strip
- **Maximum IAB length**
  - Possibly up to 120m?

INTEGRAL BRIDGE DESIGN IN SA

Some of the important areas to focus on at design stage:

- Deck end span and abutment load effects
- Concrete E value and drying shrinkage
- Deck temperature changes (effective deck temp and temperature gradient)
- Reinforcement for crack control – thermal and shrinkage movement is restrained
- Movement of the abutment