Degradation of Concrete Bridges by Internal Expansive Reactions – Portuguese Case Studies

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Context

- Several reinforced concrete bridges have shown premature degradation
Context

- An research and experimental program conducted by LNEC
  - Internal expansive reactions
  - Alkali-silica reaction (ASR)
  - Delayed ettringite formation (DEF)
In Portugal the problem is real and justifies the growing concern about the development of this type of concrete degradation.
The problem

- The diagnosis requires technical expertise

- The distinction between deleterious and non-deleterious products (e.g.: ettringite)

- The field symptoms are not exclusive of internal expansive reactions
Methods of diagnosis and prognosis

- Macroscopical aspects
  - element or structure type
  - exposure conditions (wetting-drying cycles, permanent immersion, etc.)
  - concrete composition
  - concrete application

- Microscopical material aspects (lab tests)
Methods of diagnosis and prognosis

- **Sampling**
  - extraction of concrete cores in cracked and sound areas
  - cores should be deep enough to be representative of the maximum temperatures reached in the concrete elements

- **Characterization techniques**
  - Optical microscopy and/or electronic microscopy
  - Chemical analysis (alkalis and sulphates profiles)
• Characterization techniques
  • Residual expansion tests on concrete cores
    • Avoiding the interception with cracks or reinforcement rebars
    • Recommended diameter is 10 cm
    • Length representative of the interior of the concrete element
Case studies

- Bridge located in the centre of Portugal (1976-79)
Case study: Bridge located in the centre of Portugal (1976-79)

Diagnosis tests – optical and scanning electron microscopy

DEF and ASR expansive products (alkali-reactive quartzitic aggregate)
Case study: Bridge located in the centre of Portugal (1976-79)

Prognosis tests- concrete residual expansion tests

Exist potential for future concrete expansion due to ASR and DEF, even in non-cracked areas
Case studies

- Bridge located in the north of Portugal (1994-97)
Case study: Bridge located in the centre of Portugal (1976-79)

Diagnosis tests – optical and scanning electron microscopy

ASR expansive products (alkali-reactive granitic and quartzitic aggregates)
Case study: Bridge located in the centre of Portugal (1976-79)

Prognosis tests – concrete residual expansion tests
Conclusions

• The internal expansive reactions (ASR and DEF) are a problem of durability of concrete structures requiring the adoption of appropriate methodologies for its diagnosis and prognosis.

• The diagnosis and prognosis methodology presented explains the degradation causes and allows to predict the evolution of the phenomenon and its consequences for the structure and supports the decisions taken about the repairing options in the structure elements.
Conclusions

• The two case studies presented show that this disease affects mainly massive elements and concretes with high cement contents. Furthermore, the cements used do not contain any type of mineral pozzolanic additions (fly ash, metakaolin, etc.).

• Today is well known that one of the mitigation measures of ASR and DEF during the design and construction of new structures is the use of type II additions, with or without cement replacement. The performance of each addition in the mitigation of these reactions depends on its content and pozzolanic activity. In order to verify the long-term behaviour of different mineral additions in the mitigation of these expansive reactions in concrete an important experimental program is being conducted by LNEC.
Thank you