LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

# TERCENAS BRIDGE

## A chloride induced corrosion case

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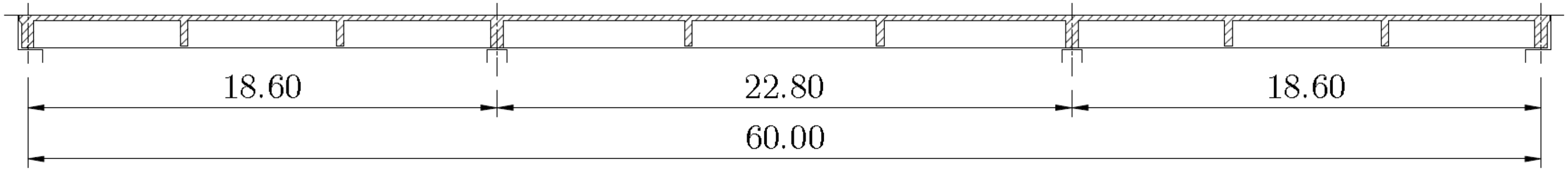
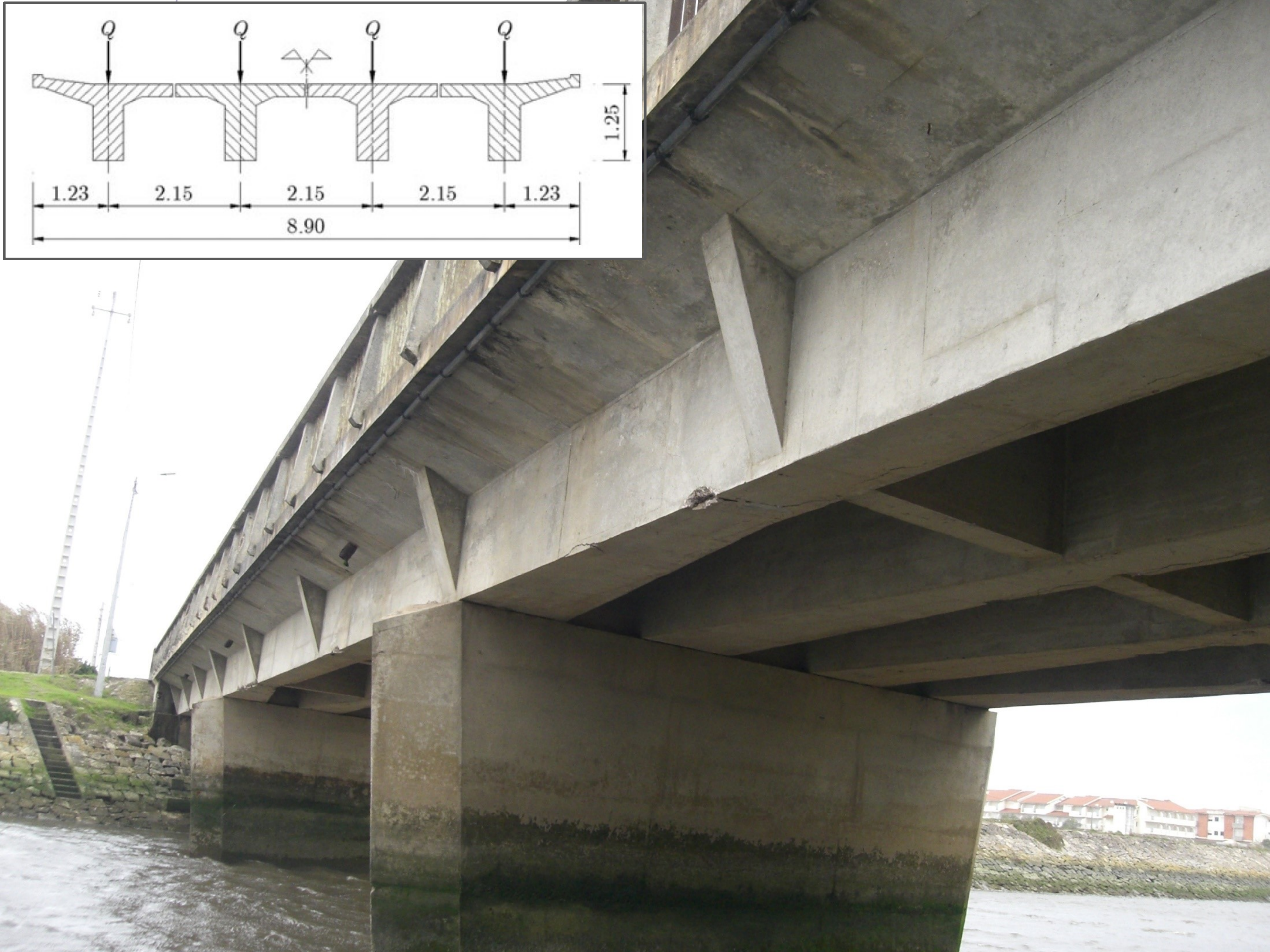
# Tercenas Bridge

Owner......Office of Water Services
Construction.........................1970





Q
Q
Q
Q
1.25
1.23
2.15
2.15
2.15
1.23
8.90

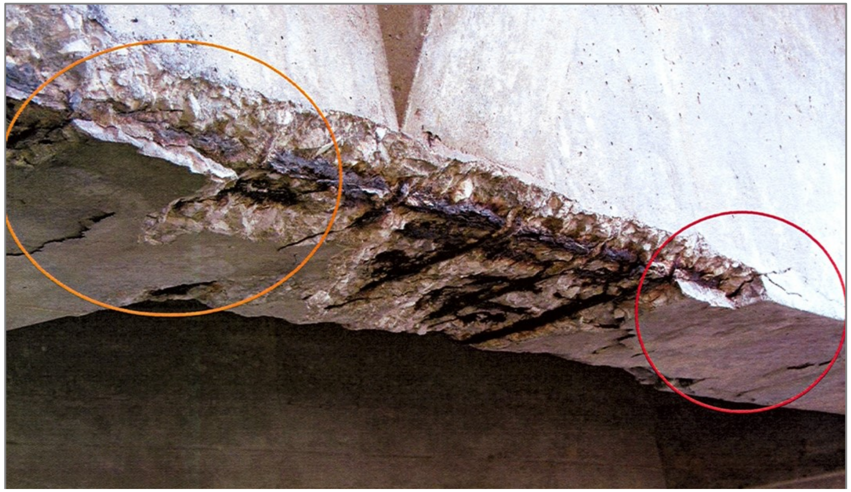
# Location


Estrada Florestal
500 m
Bairro da PSP
Rua das Tercenas
Rua da Lagoa
Praia da Vieira
N349
Rua do Mar

# Visual inspection
## Structural damages

Sep. 2004

- Cracking
- Concrete delamination
- Corrosion of reinforcement bars



Beam on the sea side (left beam)

# On-site tests

In areas without apparent degradation of the concrete:

- Determination of concrete cover depth
- Measurement of carbonation depth
- Measurement of corrosion potential (ASTM C876:91)
- Measurement of corrosion rate (RILEM TC-154-EMC, 2002)
- Measurement of resistivity of concrete

Measurements at Beams 1, 2 & 4; South pier; South Abutment

Manuel Salta *et al* . (2005).

# Laboratory tests

Taking cores for testing:

- Chloride content of concrete
- Carbonation of concrete
- Compressive strength of concrete
- Microscopic analysis

# Conclusions and recommendations from the tests

Taking into account:

- The advanced state of degradation of the bridge
- The very depth contamination of concrete with chlorides.

Bridge replacement was recommended.

# Bridge visual inspection
# Structural damages

Jan. 2008

# Bridge visual inspection
# Structural damages

April 2009

# Safety until replacement ?

- Traffic restrictions
  - Speed limit
  - Maximum weight
  - Avoid traffic over the left beam

- Frequent visual inspections

Traffic restrictions

# Tercenas Bridge: the problem

- Bridge inspection → High level of degradation (corrosion)
- Lab tests (cores) → Chloride induced corrosion
- Decision: bridge replacement
- Question: is the bridge safe until replacement ?
- Code-based safety assessment: Not safe
  (Critical limit state: bending at mid-span of the central span)
- Reliability analysis based on prior information: Not safe

# Tercenas Bridge: the solution

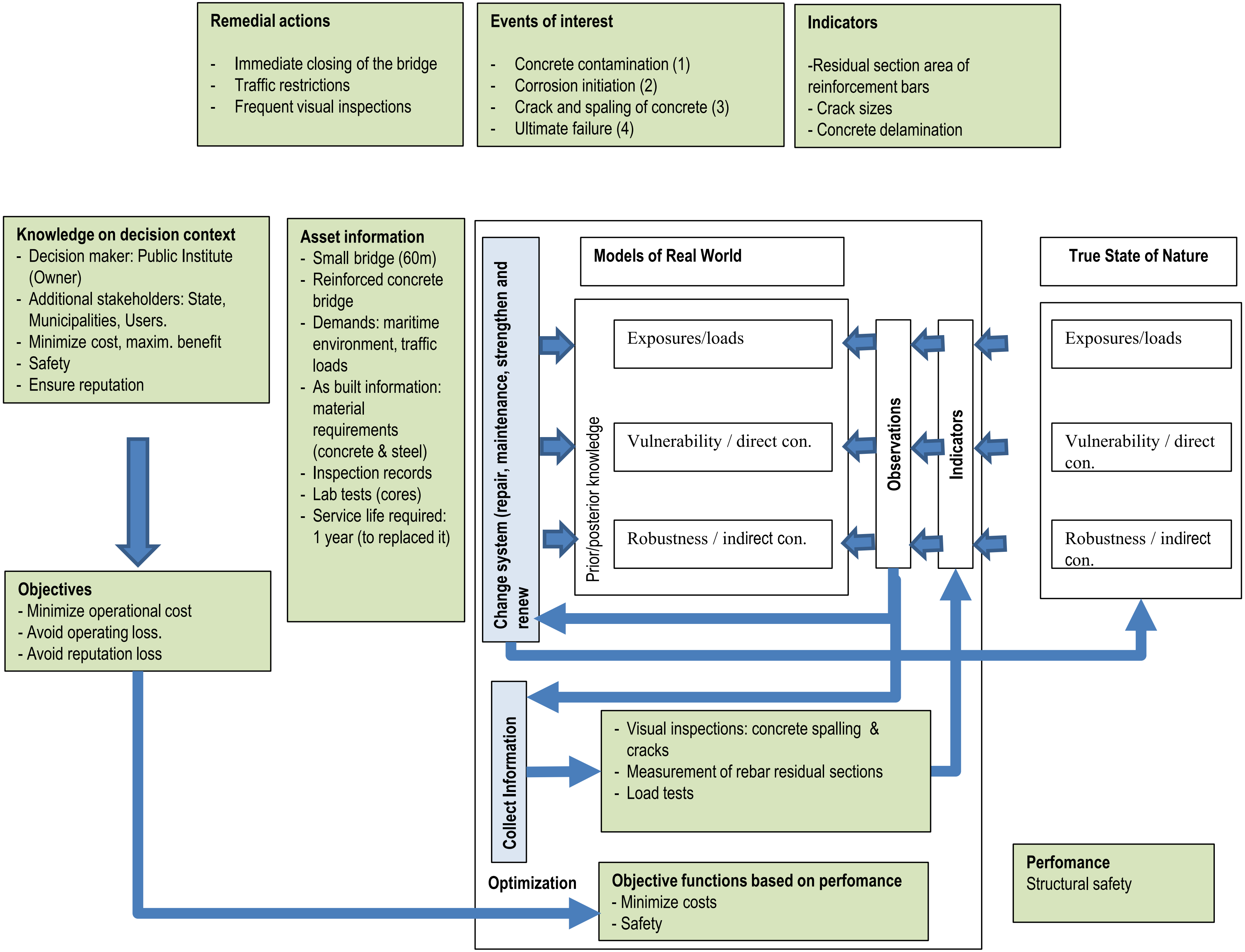
- Sensitivity analysis to identify the random variables more significant to structural safety $\rightarrow$ Residual section index ($i_{res} = A_{res} / A$)
- Collect information on key variable ($i_{res}$)
- Updating the residual section index predictive model $\rightarrow$ Bridge safe

# Implementation of a VoI analysis

- Decision maker : public institute (Portuguese Office of Water Services)
- System temporal and spatial boundaries
  - Time for replacement
  - Seaside beam: bending at mid-span of the central span
- Events of interest
  - very depth contamination of concrete with chlorides
  - corrosion initiation of reinforcement bars
  - crack and spalling of concrete
  - the ultimate failure

# Implementation of a VoI analysis

- Indicators
  - Cracks and spalling of concrete
  - Residual section area of reinforcement bars
- Basic decision alternatives
  - Close down the bridge
  - Carry out a structural assessment and base further decisions on its results.
- Simplifications
  - To consider the formation of a plastic hinge at mid-span of the central span as the critical scenario



Remedial actions
- Immediate closing of the bridge
- Traffic restrictions
- Frequent visual inspections
Events of interest
- Concrete contamination (1)
- Corrosion initiation (2)
- Crack and spaling of concrete (3)
- Ultimate failure (4)
Indicators
-Residual section area of reinforcement bars
- Crack sizes
- Concrete delamination
Knowledge on decision context
- Decision maker: Public Institute (Owner)
- Additional stakeholders: State, Municipalities, Users.
- Minimize cost, maxim. benefit
- Safety
- Ensure reputation
Asset information
- Small bridge (60m)
- Reinforced concrete bridge
- Demands: maritime environment, traffic loads
- As built information: material requirements (concrete & steel)
- Inspection records
- Lab tests (cores)
- Service life required: 1 year (to replaced it)
Change system (repair, maintenance, strengthen and renew
Models of Real World
Prior/posterior knowledge
Exposures/loads
Vulnerability / direct con.
Robustness / indirect con.
Observations
Indicators
True State of Nature
Exposures/loads
Vulnerability / direct con.
Robustness / indirect con.
Objectives
- Minimize operational cost
- Avoid operating loss.
- Avoid reputation loss
Collect Information
- Visual inspections: concrete spalling & cracks
- Measurement of rebar residual sections
- Load tests
Optimization
Objective functions based on perfomance
- Minimize costs
- Safety
Perfomance
Structural safety

# Questions & obstacles

- Starting point:
  - Before on-site and lab tests (chloride content of concrete,  compressive strength of concrete, measurement of corrosion rate, etc.
  - After the decision of replacing the bridge
- Direct and indirect costs

# Assumptions & procedures to be standardized

- Quantification of “reputational” costs caused by structural failure