Cable Dehumidification Systems for Suspension Bridges

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UK Bridge Locations

- Forth Road Bridge
- Severn Bridge
- Humber Bridge
- Tamar Bridge

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US Bridge Locations

Chesapeake Bay Bridges
Conventional Cable Protection

- Wire wrapping
- Red lead or zinc paste
- Paint (neoprene wrap on Bay Bridge)
- Galvanized wires (or strands)

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Conclusions -
cables were well maintained but in spite of this there was evidence of water inside....

Recommendations -
carry out an internal cable inspection
Internal Cable Inspections - Summary

- NCHRP 534 Guidelines – Guidelines for Inspection and Strength Evaluation of Suspension Bridge Parallel Wire Cables
- Internal Visual Inspection of Cable (Stage 1 – 4)
- Testing of Sample Wires (Strength of Stage 1, 2, 3, 4)
- Statistical Assessment to Determine Strength of Cable
Forth Road Bridge Internal Cable Inspection

External corrosion

Broken wires

Internal corrosion
Strategy for Cable Preservation: Understanding the deterioration process

Stage 1
Stage 2
Stage 3
Stage 4
Broken
Strategy for Cable Preservation: Understanding the deterioration process

- Wire “cast diameter” causes tensile stress when wire is straightened under dead load
- Wires susceptible to brittle failure due to the fabrication process – formulation of alloys and “cold working” into final diameter
- Cable microenvironment (water, contaminants, zinc, iron) produces hydrogen molecules that drive the growth of cracks
- Crack propagation and breakage is aided by the tensile stress in the wire
- Cracks can and do initially form in wires that are in good condition
- The key to long term preservation – permanently alter the cable microenvironment before cracks
Strategy for Cable Preservation: Cable Dehumidification

- Developed for Akashi Kaikyo Bridge in Japan
- Advantages:
  - Tackles cause of corrosion by removing water
  - No adverse effect on cables
  - Can see results through monitoring system
Making the cables airtight – wrapping

Cable has to be over-wrapped to make airtight

And the two layers heat bonded together to seal

Long service life expected with virtually no maintenance

Triple overlap

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Making the cables airtight – cable band sealing

Wrap & seal

Install wedge & seal

Finish
Injection and Exhaust Sleeves

Injection sleeve

Exhaust sleeve
Main Cable Access – Gantries

Worker/Material Hoist

Gantry at tower top

Severn Gantry
Main Cable Access - Catwalks

- Full length catwalks installed to allow access by multiple trades at different times to different parts of the cables
Access – Boat and Stair Tower Access
Plant Rooms – Roadway Level (Forth Bridge)
Plant Room – Anchorage (Bay Bridge)
Monitoring & Control System – web interface

HESSLE MAIN SPAN PLANT ROOM

Remote Mode

PROCESS FAN
Running Fault Dry Filter
13 Running
14 Fault
15 Dry Filter
16 Running

Target Injection Pressure (Pa)
0 100
2500.0
2500.0
2500.0
2500.0

Fan speed (%)
0 100
60.0
67.0
92.0
90.0

Actual Injection Pressure (Pa)
0 100
2513.0
2497.1
2483.6
2483.4

GENERAL RESET
REMOTE RUN
INTRUDER RESET

RUNNING ML 100 Dehumidifier (%)

Fresh Air Damper (%)

Heater Output (%)

FAULT MONITORING AND CONTROL

EMERGENCY STOP OPERATED LOW FLOW
DEHUMIDIFIER FAULT HIGH NOX LEVEL
PLANT FIRE ALARM INTRUDER ALARM
HIGH TEMPERATURE HEATER-HIGH TEMPERATURE
HEATER FAULT REACTIVATION FILTER BLOCKED
6/25 FILTER BLOCKED BRIDGE FIRE ALARM

HESSLE MAIN SPAN PLANTROOM PLAN VIEW

SMOKE DETECTOR
PRESSURE SENSOR
TEMPERATURE SENSOR

INLET ShaneOCTOBER
OUTLET DYNAMIC PRESSURE
HEPA FILTER
MANUAL DAMPER
MANUAL VALVE
FIRE DAMPER

STAIRS UP

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Draining water from mid span exhaust sleeve during initial drying

Opening sensor boxes facilitate inspection or replacement
Cable Management - Acoustic Monitoring

Sensor mounted on cable band

Installation of signal cables down suspenders
Beneficial Effect of Main Cable Dehumidification on Reducing Wire Breaks

Before dehumidification

Initial drying period

RH<40%

Injection RH increased
Media attention

The projects have attracted considerable media attention, in national press, international engineering press and local tv.

Dehumidifiers slow Forth Road Bridge cable corrosion
28 February 2013 | By Declan Lynch

Corrosion of the Forth Road Bridge’s main suspension cables has significantly slowed down following the installation of a dehumidification system, according to an official report published this week.

Study into Forth bridge dry-out
A study into the possibility of installing a drying-out system for suspension cables on the Forth Road Bridge is expected to get the go ahead.

It follows a report which warned the bridge could be shut to all traffic in under 14 years unless action was taken. Consultants are to look into fitting £12m de-humidification equipment, which would pump dry air onto the wet cables. The Forth Estuary Transport Association (Feta) is set to appoint engineers Faber Maunsell later this month.

Excellent track record
"The team Faber Maunsell has put together to carry out this study brings together the very best in experience across the world in dealing with similar situations. They have an excellent track record in understanding the complex issues involved in tackling corrosion in suspension bridges and, most importantly, providing the right solutions."
Conclusions

- The main cables of existing suspension bridges have been found to have heavily corroded and broken wires, in spite of good maintenance.
- Traditional cable protection systems alone (paste, wrapping wire and paint) have not provided adequate corrosion protection.
- Water is clearly driving the deterioration process.
- Cable dehumidification has been successfully applied to reduce the RH within cables and suppress the rate of wire deterioration.
- Dehumidification system maintenance and operation is undemanding if appropriately considered at the design stage and in the longer term, effective performance and energy use are key considerations.
- Acoustic monitoring systems and internal cable inspections used to monitor future (reduced) rate of deterioration.
Thank You

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