Durable Post-Tensioned Concrete Structures
TR72
Concrete Bridge Development Group July 2011
Gordon Clark
Director Ramboll, Former Chairman Gifford
CBDG 26 June 2002

• Last update to CBDG conference 9 years ago
• A long journey started in 1991, 20 years ago
Durable Post-Tensioned Concrete Bridges

An update and background to Concrete Society Report
TR47 Second Edition

26 June 2002
Durable post-tensioned concrete bridges

Report of a Working Party of the Concrete Society
in collaboration with the Concrete Bridge Development Group

This fully revised and updated edition of Technical Report 47 provides bridge engineers with authoritative, practical guidance on designing, specifying and constructing durable post-tensioned concrete bridges. A multi-layer protection approach to durability of post-tensioned construction is presented which has been developed by an intense collaborative effort by a Working Party of leading bridge engineers, materials specialists, contractors and bridge owners.

Prescribed concrete is, in many respects, an ideal material for bridge construction. However, some examples of tendon corrosion have come to light and led to concerns including a temporary ban in the UK on commissioning new bridges of one grade. A Working Party of concrete and corrosion experts in collaboration with the Concrete Bridge Development Group has developed a multi-layer protection approach for achieving durable post-tensioned construction. When this approach is followed for new post-tensioned concrete bridges, it will have the effect of improving their durability performance in practice very significantly over previous approaches.

The standards and practices outlined in the core of the Report are a compatible package of design, materials and construction measures. For the pre stressing system itself, the basis of the recommendations is one of quality, linking together three inseparable aspects: recommended design details, specifications for duct and grouting systems, and a quality assurance scheme for supply and installation of post-tensioning systems.

Test methods for grout materials and duct systems are reviewed, and results of research and site trials undertaken in conjunction with the Working Party are summarized with up-to-date information of new techniques developed since 1996.

Durable Post-tensioned Concrete Bridges provides bridge owners and specifiers with the technical basis for continuing successful use of post-tensioned concrete for durable bridge construction.

Concrete Society Technical Report 47, Second Edition
Publication date June 2002. Orders placed before publication will be fulfilled as soon as the Report is available. Approximately 60 pages, £80 (Members of The Concrete Society £40)

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Now

Revision 3 of CS Report now including Buildings – 2010

renamed TR72 because of significant revisions
A resume of the background

• What was the fuss about?
• New developments
• Where are we now and what next
An early UK problem Braidley Road Bridge built 1968
All prestressing replaced late 1970’s
Incompatible materials in corrosion protection?
1977 UK ban on external post-tensioning in bridges

- This and other problem bridges led to a major rethink about corrosion protection and replaceability
M25 New Haw Viaduct 1980 – internal prestressing
1985 Collapse Ynys-y-Gwas
UK CBDG/Concrete Society Committee

- First convened 1991
- George Somerville (BCA – and CBDG being founded)
- Gordon Clark (Gifford)
- Mark Raiss (Benaim)
- Mike Walker (Concrete Society)
1992 Collapse in Belgium

1992 UK ban on internal prestressing for bridges
Design relied on uninspectable buried tie-down
Taf Fawr Bridge 1964. Major corrosion
Rebuilt 1995
Major concern about corrosion

- Poor design details
- Poor grouting
- Salt attack
- Unable to inspect internal tendons
Sudden collapse often possible in bonded tendons

19 strands @ 70% = 13 strands @ 100% if grout bond holds load
Major Investigations - Filling the Ducts
Improving grout – *not at this stage*
Full Scale Trials – still some problems
Camel Viaduct – externally prestressed 1993

- Replaceable, restressable tendons
- New design rules for redundancy
Camel Viaduct – externally prestressed 1993
Prototype for some details
Durable Bonded Post-tensioned Concrete Bridges

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TR47 published 1996
Key aspects required

• Must fill the duct
• Non-bleed grout
• Non-shrink grout
• Multi-layer protection
  – Waterproofing
  – Cover
  – Plastic Duct
  – Anchorage caps
  – Vents properly sealed
• Detail to avoid water penetration
UK was out on a limb still

- HA lifted the ban on internal post-tensioning except precast segmental
- Problem not yet acknowledged in other countries
- More UK research and development especially on grouts
- Fib work started in 1997
Swiss survey 1998
107 bridges – 13% had grouting deficiencies
Anglo – French study 1999

163 bridges – 12% not grouted
New Inclined Tube Stability Test (French)
Inclined Tube Test - Results:

Photograph courtesy VSL
Standard Bleed Tests - Results:

Grout with good performance in Inclined Tube Test

Grout with poor performance in Inclined Tube Test
Wick-Induced Bleeding of Grout

Grout with poor performance in Inclined Tube Test

Grout with good performance in Inclined Tube Test

Photograph courtesy VSL
US Experience – Mid Bay Bridge
Mid Bay Bridge Florida

- Built 1992
- 138 spans
- Voids in Anchorages
- Corrosion in Tendons
- Powdery Grout
- Broken Tendons
- Cause – POOR GROUTING – more than 700 voids
- Repair cost over $1m in 2001

- ONLY 9 Years
Testing
1997 Virginia failure
Vertical prestressing inside Sunshine Skyway Piers
Anchors in pockets

- Smooth PE Duct
- Smooth PE Duct inside Corrugated PE Duct
Leaking epoxy joints in segmental deck
Typical precast segment

- Top Slab Keys
- Top Temporary PT Bars
- Bottom Continuity Anchor Blister
- Bottom Slab Keys
- Cantilever Tendons anchored on the segment face
- Cantilever Tendons anchored in blisters and the Anchor for Top Continuity Tendons (when reversed)
- Web Shear Keys
- Bottom Continuity Tendons
- Bottom Temporary PT Bars
US Research & Development
New Directions for Florida
Post-Tensioned Bridges

Volume 1 of 5:
Post-Tensioning in Florida Bridges

Corvon Engineering, Inc.
1415 E. Plodmont Drive, Suite 2
Tallahassee, Florida 32308
Tel: 850 386-6800
Fax: 850 386-9374

February 15, 2002
New requirements

- Improved grouts
- Non-bleed
- Non-shrink

- New tests
- Inclined tube
- Wick test for bleed
- Density
Second Edition 2002
Major changes to testing
Followed emerging fib guidance
Footbridge Concord, North Carolina 2004
International guidance fib 2000 - 2005
Post-Tensioning Tendon Installation and Grouting Manual

2004 FHA
US Guidance

May 26, 2004
Further US research

Nondestructive Methods for Condition Evaluation of Prestressing Steel Strands in Concrete Bridges

Corrosion from Bleed Water in Grouted Post-Tensioned Tendons

by Matthew D. Bricker and Andrea J. Schokker
Further product Development - systems

Protecting internal tendons with VSL PT-PLUS

Encapsulating internal post-tensioned tendons with VSL PT-PLUS plastic ducts for concrete in segmental bridges has several advantages over the use of traditional metal ducts:

- The VSL PT-PLUS plastic ducts remain intact even under application of large axial stresses and tendons elongations during stressing.
- The VSL PT-PLUS plastic ducts offer significantly higher fatigue strength and remain intact across large temperature changes at long-term temperatures.
- VSL PT-PLUS plastic ducts reduce friction losses during stressing but provide sufficient bond for fully bonded tendon design.

In addition, the VSL segmental duct coupler represents a major development in the provision of fully encapsulated post-tensioning tendons at precast segmental construction. Monitoring can be used to track performance of tendons in the critical construction process.

High strength for high protection

Deltalit is a material with unmatched strength and durability that has been developed jointly by Bouygues TPR and Lafarge and is marketed by VSL for specific use; it generates a 20-fold increase compared to conventional concrete properties. Deltalit is a very dense material, and thus has...
Further development – precast duct couplers
Further Development - grouts

**MASTERFLOW® 1341**
Universal post-tensioning grout

**1121 GROUT**
(CABLE DUCT GROUT)

**TECHNICAL DATA**

**CABLE GROUT**

High-performance, pumpable cementitious grout for grouting post-tensioned tendons
European and other Standards

- EN445
- EN446
- EN447
- EN13670
- ETAG013
- CWA 14646
- CARES Model Specification
- NSCS
- ISO’s being developed
Grout for prestressing tendons — Test methods

Grout for prestressing tendons — Grouting procedures

Grout for prestressing tendons — Basic requirements
Further UK problems since TR47 v2
Grouting ducts in Buildings

- Realisation that not just bridges affected
- Post-tensioned car park slabs – problems found
- Study indicated quite widespread problems
  - Empty or partially filled ducts
  - Bursting of cover
- Commonly still used cement/water mix
- Mainly steel ducts and exposed anchors with low cover
- Needed a careful review and improvement to practice
Leaky waterproofing
Water in grout vents
(UK discovered 2011)
New rules would prevent
Post-tensioned floors 1990’s

- Careful design is critical
- Some resistance to use
- Major economic benefits (construction depth) in tall buildings
- Minimise slab thickness on multi-storey – extra floors in same height building
- Vibration has to be considered
Survey - Types of Problems

• Ungrouted ducts
• Partially grouted ducts
• Cover bursting due to excess grouting pressure or freezing of water in duct
• Poor design detailing of anchorages
• Lack of care in positioning and detailing tendons
• Late changes to Holes in slabs causing repositioning
National Structural Concrete Specification to EN13670

Published 2010

Updated to latest UK practice
TR72

Main changes from TR47 2nd edition....
Main changes from TR47 2nd Edition 2002

- Updated to align with ENs for grouting
- Some slight departures (more stringent incorporating UK ideas since EN’s published)
- Specification removed – refer to ENs where possible
- Test methods removed – refer to ENs
- Include recommendations for buildings based on further experience
- Update on Quality Scheme requirements
- CARES Scheme improved in parallel
What next?

- ISO Draft International Standards
- Launched at ISO TC71 meeting 17 June in Hong Kong
- Implementation in UK of stricter surveillance by CARES
- Further Development of technology to monitor new structures
- Lots of older UK post-tensioned structures still under investigation
  - especially Network Rail
- European Standard for Plastic ducts to be developed
- Adapting Specifications for new Nuclear Use for HSE
- Grouting standards relatively mature – for a while
Finally

May I encourage you or your organisation to consider joining the fib UK group and support the UK Concrete Industry internationally

www.fib-international.org
Objectives of *fib*

… to develop at an international level the study of scientific and practical matters capable of advancing the technical, economic, aesthetic and environmental performance of concrete construction.
Why join UK fib Group?

• Enables member to:
  – join with other participating UK companies to collectively participate in and influence the work of fib commissions and task groups
  – network with other leading UK organisations
  – receive regular free cutting edge international publications, including back issues of bulletins
  – sustain UK national membership of fib
Members of UK *fib* Group

- Arup
- Atkins
- British Precast Concrete Federation
- BRE Ltd
- Celsa Manufacturing
- Associate IStructE
- Gifford/Ramboll
- Parsons Brinckerhoff
- The Concrete Centre
- The Concrete Society
- UK CARES
- Joining
  - University of Bath
Network of contacts

• Fib is THE international concrete network
• Fib organisation – National Delegates from 43 countries
• Commission Members
• Academics, Professors, Contractors, Consultants, Suppliers
• Links to JCI Japan, ACI US and Concrete Institutes, Bodies and Universities across the world
• Symposia and Conferences
• State-of-the-art reports and guidance
Thank you for your attention