Non-destructive testing for special inspection of post-tensioned bridges

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ABSTRACT

Post-tensioned (PT) concrete bridges are vulnerable to tendon corrosion due to voids in poorly grouted ducts, leading to potential structural deficiencies. This study presents a special inspection methodology combining non-destructive testing (NDT) and selective core drilling to assess the tendon condition of Gisund Bridge. Ground Penetrating Radar, Ultrasonic

Tomography, and Impact Echo were used to detect voids, with core drilling validating findings. Results revealed significant grout deficiencies in multiple tendons.
The study highlights the importance of integrating NDT and semi-destructive testing for effective PT bridge assessment.

Key words: Testing, Corrosion, Durability

1. INTRODUCTION

Post-tensioned (PT) concrete bridges have been widely used since the late 1950s due to their ability to support long spans efficiently while remaining cost-effective. While initially believed to be maintenance-free with a lifespan of 120 years, experience has shown that PT bridges are susceptible to hidden deterioration, particularly corrosion of the internal tendons. A major contributor to corrosion in PT systems is grouting deficiencies, which can result in voids within tendon ducts. These voids, caused by trapped air, grout bleeding, or incomplete filling, leave the strands vulnerable to moisture and chloride ingress. Unlike conventional reinforced concrete, where defects are often visible, PT bridges conceal critical damage, making deterioration difficult to detect. Visual inspections alone are often insufficient, and while intrusive investigations such as coring can confirm damage, they are costly and may compromise the structure. To address these challenges, non-destructive testing (NDT) has become an important tool for assessing PT bridges, allowing for early detection of corrosion due to the presence of voids without invasive procedures. This paper outlines a structured approach to special inspections of PT bridges, integrating NDT, coring for verification, and targeted local repairs. The methodology is demonstrated through a case study of Gisund Bridge.

2. METHODOLOGY

The special inspection of PT concrete bridges follows a structured approach consisting of three key phases: (1) Preliminary Desk Study, (2) Preliminary Site Inspection, and (3) Detailed Site Investigation. Each phase is documented in a report outlining findings, defining work to be carried out, and detailing the technical plan for subsequent steps.

2.1 Preliminary desk study

A thorough desk study serves as the foundation for the inspection by reviewing the bridge's original design, construction records, and past inspection reports. Construction records are analyzed to assess potential risks associated with grouting deficiencies and void formation, which are primary contributors to tendon corrosion. Discussion with relevant actors (e.g public roads administration and bridge owners) are also undertaken to gain a thorough understanding of the history of the bridge.

2.2 Preliminary site inspection

This phase involves an initial visual examination to verify structural details, access and potential damagedareas. Observations focus on cracking, water ingress, cracking, and steel corrosion. A representative selection of tendons is examined to evaluate grouting conditions. Since inspecting all tendons is impractical, the inspection at this phase is focused on a single span, where sampling is strategically distributed to cover the most critical areas, ensuring a comprehensive condition assessment. If severe defects are identified, the investigation scope is expanded to additional critical sections.

2.2.1 Non-destructive testing

The primary objective of this phase is to assess tendon duct conditions, grout integrity, and corrosion activity. Non-Destructive Testing (NDT) methods are used first, minimizing invasive procedures, while semi-destructive coring is performed selectively for verification.

Ground Penetrating Radar (GPR) – Used to detect tendon locations and duct alignment. Data is collected in 2D scans, with positions marked directly on the concrete surface for reference. After identifying the ducts, the profile line is divided into 10 cm segments to ensure precise documentation and further testing.

Ultrasonic Shear Wave Tomography (MIRA) – Provides 2D cross-sectional images of tendon ducts using ultrasonic waves. Multiple slices taken at 10 cm intervals are compiled into a 3D model for defect analysis.

Impact Echo (IE) – Applied to validate anomalies detected through MIRA. An acoustic impact generates stress waves, which reflect from internal voids or defects, revealing discontinuities.

Semi-Destructive Testing (SDT) – Exploratory Coring is conducted in suspected void areas to confirm NDT results. Through coring into the duct, following established protocols, a direct inspection of grout integrity, tendon conditions, and void presence can be completed. A fiber-optic camera (endoscope) inserted through drilled access holes provides internal visuals of ducts and tendons, offering additional confirmation.

3. CASE STUDY: GISUND BRIDGE

The Gisund Bridge, a 1,147-meter-long cantilever road bridge in Norway, was inspected using a combination of non-destructive and semi-destructive methods to assess the condition of post-tensioned tendon ducts. The inspection focused primarily on two spans, with selected results presented here.

Figure 1 – NDT process

The first objective of the investigation was to identify the exact positions of prestressed tendons to facilitate further assessment of grouting conditions. GPR was used to map the tendon layout. To evaluate the grouting status, MIRA was used across the test locations. Approximately 950 B-scans were collected, showing strong reflections in multiple areas, indicating discontinuities in material properties. In many cases, tendon ducts exhibited high reflectivity (red zones – see Figure 2), suggesting voids and incomplete grouting. This was particularly evident in both the north and south girders, with multiple tendons displaying signs of missing grout or insufficient filling. Impact echo testing was attempted to validate ultrasonic findings, but due to Alkali-Silica Reaction (ASR) in the concrete, reliable results could not be obtained. The presence of microcracks and scattering effects from ASR affected wave propagation, complicating defect detection.

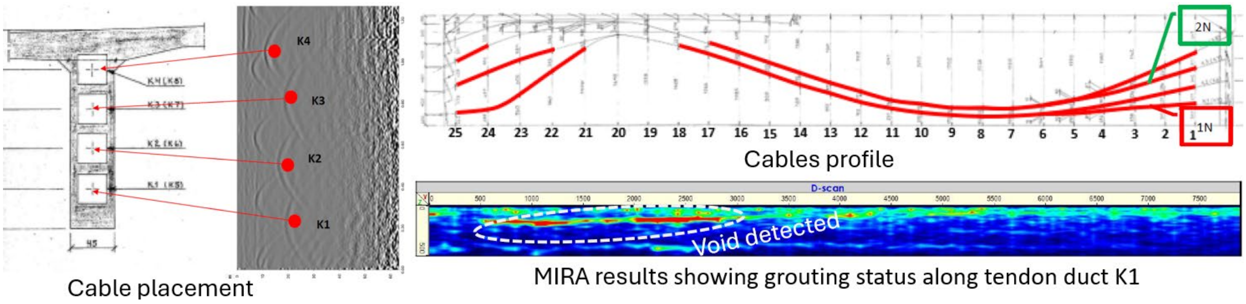

Figure 2 – NDT results showing void detection along tendon ducts

To verify the extent of voids detected through NDT, a total of 27 openings were made in 15 different cables. The findings confirmed that several ducts were partially or completely ungrouted (Figure 3), particularly in two ducts located in similar locations but opposite sides of the bridge. While grout was entirely lacking, only minor surface corrosion was observed on the strands, with no significant structural damage being found. At another location, however, a void was found near a joint with semi-destructive testing revealing wet grout and severe strand corrosion.

Figure 3 –Validation of NDT results showing voids detected through coring and endoscope

Once verification openings are made, they must be properly restored to maintain integrity. Small openings are repaired using high-bond adhesives, while larger openings require sealing barriers to prevent grout contamination in empty ducts. Finally, corrosion protection and shrinkage-compensated mortar ensure durability and prevent further deterioration.

4. RESULTS AND DISCUSSION

The Gisund Bridge investigation revealed widespread grout deficiencies. Routine inspections cannot detect voids or early-stage corrosion, making reliance on traditional methods a false sense of security. Bridges with unverified grouting pose an immediate risk, requiring special inspections. Stricter regulations must enforce comprehensive NDT assessments to identify voids before corrosion compromises structural integrity. A combined approach using GPR, MIRA, and Impact Echo is essential for void detection, while coring must be used strategically. Finally, proper repair of verification openings is mandatory to prevent further deterioration.

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