Pilot Project Using Electrically Isolated Tendon Post-Tensioning System and Grout Sensors

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The State Highway 146 (SH 146) bridge bent 107 in Kemah, Tex., was selected as a Federal Highway Administration (FHWA) pilot project for an electrically isolated tendon (EIT) application, with the Texas Department of Transportation as cosponsor. Fully encapsulated post-tensioning (PT) tendons or protection level 2 (PL2) tendons provide enhanced durability performance. However, in current PT practice in the United States, it is not possible to remotely monitor the in-service condition of tendons. PT systems using EITs, or protection level 3 (PL3) tendons, provide a high level of corrosion protection and the ability to monitor PT tendon condition throughout a structure's life cycle.[1]

Technology on the SH 146 project included vacuum-assisted grouting and structural health–monitoring sensors, which were used as quality-control measurement tools during and after the grouting process. The proprietary sensors used on this project collect data while the grout is still in its fluid state to verify whether the grouting operation is complete or if a secondary injection is required. The use of the sensors eliminates the need to drill behind the anchor or bearing plate during a post-grout inspection, which is the current PT practice and can potentially compromise EIT performance.[2]

To interpret data from the proprietary grout sensors during grout placement, normal ranges for the prepackaged grout are established by mixing grout at the correct water-cement (*w/c*) ratio and at an excessive *w/c* ratio. All Photos and Figures: Structural Technologies/VSL International.

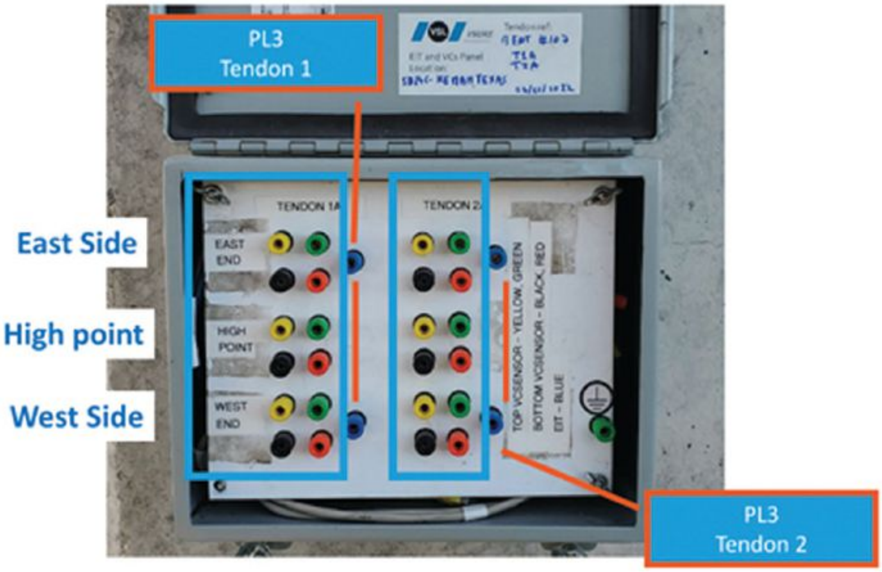
EITs were initially developed for structures with DC voltage power, such as light-rail transit. In such structures, the stray current from the electrical source can cause accelerated corrosion in the steel components of the concrete structure, including the PT strands, with serious consequences to the integrity of the structure. Stray current is not only able to travel through mild reinforcement; it can also travel through cementitious material such as concrete and grout to find its way to the PT strand. Therefore, EITs require not only complete encapsulation around the tendon envelope, but also complete electrical isolation of the PT strand from the environment outside the tendon envelope.

EIT technology has been deployed in Switzerland since the 1990s and bridge owners have found that, in addition to protecting from stray current, the system provides assurance that the PT system has been installed according to the system design.[3] As a result, the owner can have greater confidence in the quality of the PT system integrity. In addition, corrosion-inducing materials cannot penetrate the tendon without being immediately detected by the EIT system, even before corrosion occurs. On the SH 146 project, this high level of confidence was achieved by using nonconductive PT materials from end-to-end, and includes:

- permanent plastic grout caps,
- a seamless extruded plastic duct,
- a plastic trumpet that extends from the wedge plate to the duct, rather than only from the end of the bearing plate, and
- high-strength, nonconductive material that isolates the wedge plate and bearing plate.

The first two items (plastic grout caps and plastic duct) are standard for PL2 tendons. The plastic trumpet must prevent contact between the strand and the bearing plate and may require some modification to existing PT system designs or an upgrade of the anchorage plate size. The plastic trumpet is the only new piece of hardware required to upgrade a PL2 tendon to PL3. Thus, existing PT systems can be upgraded to meet the PL3 requirements with only minor modifications to the existing hardware components.

In addition to achieving electrical isolation, the PL3 standard requires the ability to monitor the tendon for electrical isolation during and after construction by nondestructive means. Monitoring is achieved by checking the electrical resistance between the PT strand and the reinforcing steel with an LCR meter. (An LCR meter is used to measure the inductance, capacitance, and resistance of a component.) The LCR meter is used to measure the impedance of the system because the tendon includes both grout (resistive material) and a plastic duct (capacitive material); therefore, a static resistance



For the pilot project, the junction box for the electrically isolated tendons was placed at a readily accessible location at ground level. The electrically isolated post-tensioning system connection to each anchorage is blue.

measurement is not appropriate. If the tendon is electrically isolated, the resistance (ohms) of the grout does not reduce the measured impedance and the reading will be controlled by the resistance of the plastic duct, which is relatively high. For a continuous construction system, if the specific resistance is measured at a sufficiently high value (50 kΩ-m for each tendon), then an effective EIT has been created. A copper lead (12-gauge insulated wire) is attached to the reinforcing steel before concrete placement (ground wire), and another lead is attached to the strand or wedge plate. These wires are routed to a junction box that is readily accessible on the structure. An LCR meter is used to measure the resistance at 1 kHz. Electrical leakage can be found in a variety of measurements, such as the following:

- Very low resistance indicates a short circuit has occurred between the strand and reinforcing steel. The likely cause of a short circuit is direct steel-to-steel contact from a breakage in the tendon envelope or moisture leaking through the duct-trumpet connections and bridging the contact.
- Moderate resistance indicates that an electrical leakage has occurred by infiltration of grout, cement paste, or both through the duct connections, or by the plastic duct being compromised due to incorrect installation that caused a kink or dent in the duct on one of the reinforcing support bars.

Electrically isolated tendons after tensioning. The electrical isolation plate underneath the wedge plate creates isolation between the strands and the bearing plate.

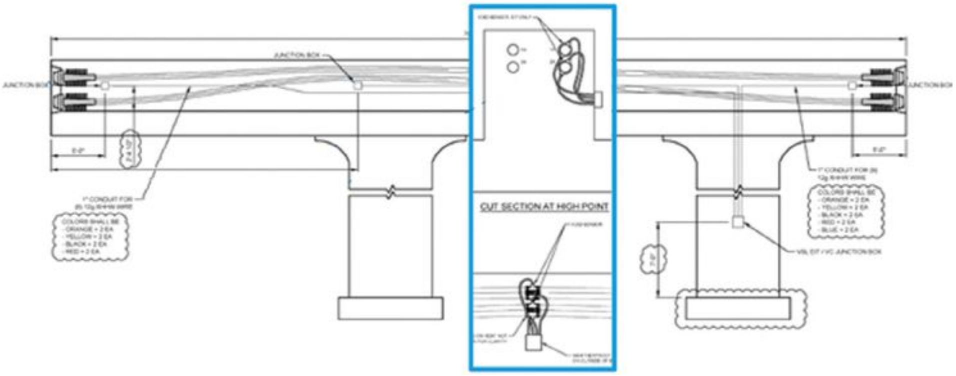
Tendon monitoring occurs at multiple stages during construction. At a minimum, it should occur at the following points:

1. After strand is installed, but before tensioning. An electrical leak at this stage indicates a severe break in the tendon envelope. This can be remedied by removing the strand, locating the break, and, if the break is in the duct, repairing it with pipe sleeve installed using an epoxy adhesive.
2. After tensioning. An electrical leak indicates a kink in the duct on the reinforcing steel. The act of tensioning causes the strand to wear through or compress the plastic to an insufficient thickness to act as an electrical barrier. This condition can be remedied if deemed necessary.
3. During and after grouting. Electrical isolation is expected to dramatically, but temporarily, decrease during grouting due to the conductivity of wet grout. As the grout cures, a logarithmic curve describing electrical isolation is expected, and electrical isolation is expected to return by 28 days.

The SH 146 project was constructed from November 2021 to May 2022 and included 20 PT straddle bent caps with cantilevered ends. The PT profile required the use of high-point grout vents. Because every grout vent creates an opportunity for electrical leakage, the final grouting plan called for removing the high-point vents and using a vacuum-assisted grouting method. This method eliminates the possibility of introducing air throughout the tendon before grouting and prevents voids in the tendon grout without the need to vent the air at the intermediate location.

Current post-grout inspection practices include drilling into the duct and trumpet for void inspection. Proprietary sensors were incorporated into the EITs on the SH 146 project to facilitate nondestructive testing. These sensors are placed at the top and bottom of the duct and anchorage. Using software, an electrochemical measurement based on the potential/pH diagram is taken to determine whether the tendon is full of grout at the location of the sensors. Through calibration, the data collected by the sensors allow the user to distinguish between well-mixed grout, watery grout, water, or a void. The sensors provide immediate feedback during the grouting process. Should an abnormal reading be found, additional grout can be pumped into the tendon to displace the defect and completely fill the tendon with high-quality grout.

A project like SH 146 does not require the use of EITs. In fact, very few PT projects have stray current concerns. However, one of the additional benefits of using a PL3 system is that the system provides the enhanced workmanship and quality control that are required to demonstrate electrical isolation. Rather than demonstrating the effectiveness of the PT system through one-time system testing and mock-ups, PL3 tendons require proof of electrical isolation for every installed tendon. With the addition of the proprietary sensors on this project, proof of quality grout filling for each tendon was also verified with nondestructive



Schematic diagram of electrically isolated tendons and sensors on State Highway 146 bridge bent 107 in Kemah, Tex. Sensors were put at the ends and the high point of each tendon.

testing. Vacuum-assisted grouting further enhances the workmanship, with all connections being completely airtight to achieve the vacuum required. After the completion of the project, the EITs can be easily checked on a regular basis for any undesirable changes in the tendon's electrical isolation. A sudden drop in isolation would indicate that the tendon envelope has been compromised and the tendon may be susceptible to corrosion. Proactive measures can then be taken to investigate and correct these defects before the tendon is beyond repair.

The FHWA EIT pilot project on SH 146 was a success. The EITs successfully met the electrical isolation requirements, and the sensors confirmed that the tendons were filled with grout. Based on this success, it is hoped that these two technologies will receive wider acceptance and implementation on future projects in the United States.

References

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