REPAIR OF PARTIALLY GREASE-FILLED ENCAPSULATED MONOSTRAND POST-TENSIONING TENDONS

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Authorized reprint from: July 2007 issue of the PTI Journal

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ABSTRACT

This article illustrates the remediation procedures required when unbonded tendons are not properly protected with grease as required by the current PTI/ACI specifications. The consequences of not following simple, but essential post-tensioning details during the construction can be very costly.

It is well known that the grease is an important element that provides protection to tendons against corrosion. It is not sufficient to manufacture good tendons, install them according to the profiles indicated in the drawings, and stress them to the required force. It is also critical that other recommended simple details are followed in order to avoid serious problems that can impact the durability and long term performance of the tendon.

Every post-tensioning project requires cutting of tendon tails after stressing operation is complete. When encapsulated tendons are used a grease cap is installed on at the end of the tendon to provide a watertight seal over the anchor. The grease cap prevents the water from accessing the anchor cavity and protects the tendon from corrosion. If the stressing tails of the tendons are cut too long, it can lead to improper installation of grease cap. Although all stressing pockets are subsequently filled with non-shrink grout, in very aggressive environments water may find a way into the anchorage cavities and tendons, causing corrosion that may affect the overall performance of the structure.

This paper describes the findings, methods, corrective actions and challenges faced during the remediation work required to correct this type of problem.

KEYWORDS

anchorage; ground penetrating radar (GPR); post-tensioning; seal tube; stressing pocket; stressing tail; unbonded tendon

PTI Journal, V. 5, No. 1, July 2007. Received and reviewed under Institute Journal publication policies. Pertinent discussion will be published in the next issue of the PTI Journal if received within 3 months from the publication.

1.0 INTRODUCTION

In typical post-tensioned building construction in North America, the vertical elements (reinforced concrete columns and shear walls) and slab on ground are typically constructed with reinforced concrete, while the elevated horizontal elements (slabs and beams) are typically post-tensioned. Depending on the application and spans the slabs could be either two-way flat slabs that span between columns or one-way slabs that span between beams which in turn span to the supporting columns. The two-way slabs typically have banded tendons concentrated along the column lines and uniformly spaced tendons in between.

In aggressive environments the Engineers typically specify that all post-tensioning be encapsulated. Encapsulation provides an additional layer of protection by creating a watertight environment for the tendons. Encapsulated tendons are also electrically isolated from the surrounding concrete and prevent the formation of any electrochemical cells which could damage the tendons. However, if the encapsulated system is not properly installed it could lead to durability issues.

2.0 THE PROBLEM (BACKGROUND)

There are two very simple but important details that if not properly implemented during the construction phase of the structure may generate a serious corrosion problem that could lead to distress in post-tensioned structures.

After completion of the stressing operations, the strand tails need to be cut to a proper length beyond the anchorages to ensure that grease caps that are designed to encapsulate the tendon anchorage and provide corrosion protection at the anchorages can be installed properly.

Approximately one ft long seal tubes, connecting the polyethylene (PE) sheathing of the tendons to the end anchorages, must be properly filled with grease. This restricts the entry and accumulation of water in the seal tubes.

Even if the stressing pockets are subsequently filled with grout, if the two details are not correctly followed, it is possible for water to enter into the tendons and cause the tendons to develop signs of corrosion. Usually these signs include rust spots that can be unsightly and call the attention to the problem. In extreme cases of corrosion tendons may fail causing concern. If signs of corrosion are detected on a post-tensioned structure it is recommended that inspection of a sample of the tendon population be conducted to determine the extent and severity of the problem. In severe cases the deterioration is often accompanied by more serious construction conditions that can cause water to come out of pockets and anchorages and multiple tendon failures. This paper describes a structure that was experiencing severe problems. The evaluation revealed construction defects from the original construction. The paper describes a technique that was used to rehabilitate and restore the corrosion protection on the tendons.

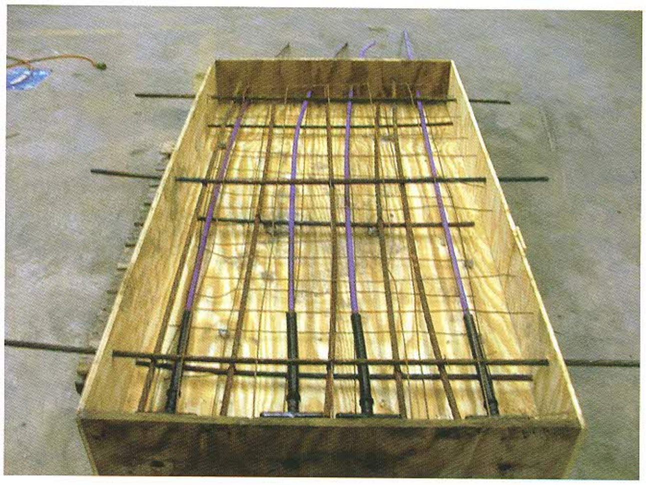

Fig. 1 - Mock-up test set-up

Fig. 2 - Close up of mock-up test set-up anchorages

3.0 THE SCOPE OF WORK

As a result of the sample inspection on the project a more in-depth inspection was required to evaluate the extent of the problem and develop strategies for corrective action. A consultant was hired by the Owner to prepare a set of specifications and drawings to effectively repair and rehabilitate the structure. The main objective of the repair was to restore the protection to the strands by injecting grease into the anchorages and seal tubes of all defective tendons along the stressing anchorage areas. In order to accomplish this objective, the following tasks were required at the site:

- Location of the tendons within the slab was determined by using GPR (Ground Penetrating Radar).
- Removal of non-shrink grout from the anchorage pockets.
- Drilling of injection ports and fittings for grease injection.
- Grease injection and verification that grease has filled all voids in the tendon.
- Cutting of strand tails to proper length and installation of new grease caps.
- Patching of stressing pockets and injection ports.

4.0 PROCEDURES

The main challenge was to select the right method that could confirm that the grease had flowed continuously and filled all voids with an acceptable level of confidence.

Since the project conditions and tendon profiles varied on the project, it was necessary to test the method with mock-ups, prior to mobilization to the site. The mock represented actual field conditions to ensure the reliability of the method. (See Figs. 1 and 2).

Fig. 3 - GPR scanning for tendon location

Once the method was selected and the crew was mobilized to the site the following procedure was used:

Location of the tendons within the slab: This task is performed from the top or bottom of the slab, with the aid of a GPR (Ground Penetrating Radar). While challenging for banded tendons due to the close spacing between the individual tendons, the technique works reasonably well. Fig. 3 shows a GPR scanning from the top of the slab. When the deck is exposed to an aggressive environment it is recommended that GPR scanning be performed from underneath the slab. Once the tendons are located drilling can also be performed from underneath the slab, reducing possibility of future water intrusion through the drilled holes or patches, after the work is completed. As the tendons are located, the drill locations are marked on the structure. (See Figs. 4 and 5).

Removal of grout filling from the anchorage pockets: This includes the removal of existing grease caps; cleaning and inspection of anchorage condition (Figs. 6 and 7 show the grout removal and Fig. 8 shows the condition of the anchorages as they are exposed). The anchorages and concrete pocket surfaces are wire brushed for cleaning. The cleaned open pocket serves two purposes: The flow of grease through the wedges is used to confirm that all void spaces have been filled. It can also be used as an injection port when practical; in this situation the hole drilled through the sheathing serves as a vent hole.

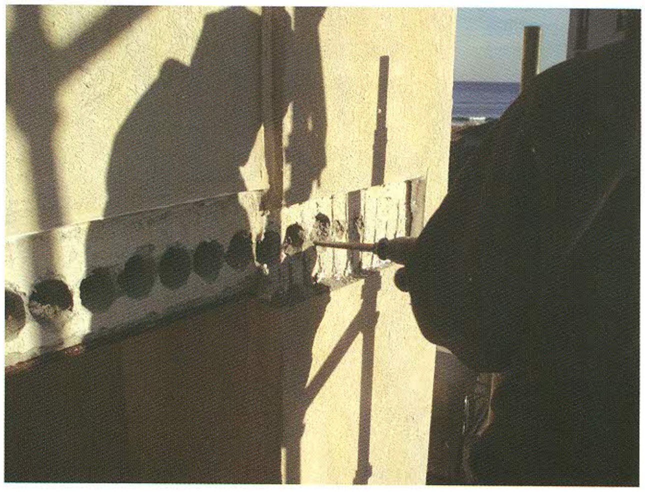

Fig. 6 - Removal of grout from stressing pockets

Fig. 4 - Marking of tendons

Fig. 7 - Exposed stressing pockets

Fig. 5 - Marked tendons at the soffit of slab

Fig. 8 - Deteriorated anchorages due to improper end-cap installation

Fig. 9 - Establishing electrical continuity with the strand tails

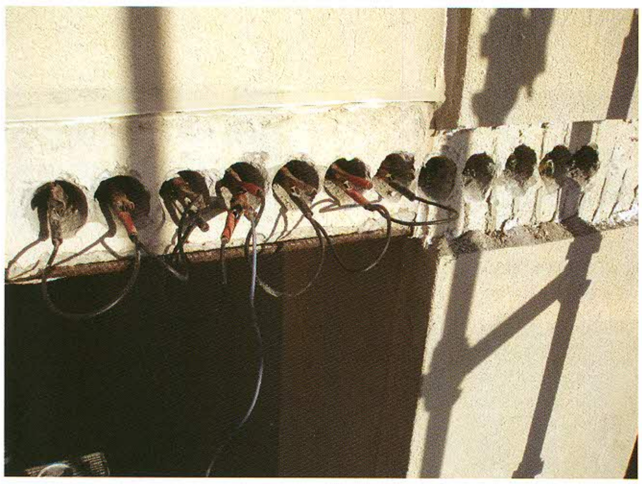

Fig. 10 - Connection to strand tails

Drilling of injection ports and installation of fittings for grease injection: Prior to the beginning of the drilling operation, it is important to implement a drilling system that will automatically shut-off when the tip of the drill bit touches metal. This is a critical step necessary to protect the prestressing steel during the drilling operation through the tendon sheathing (Figs. 9 and 10 illustrate the connection to strand tails.) Despite the fact that automatic shut-off equipment is used, careful attention is needed during the drilling operation to avoid errors. Errors could be costly and may result in a damaged strand. The drilling is done through the concrete slab and tendon sheathing at a location where the need for grease starts; it could be one to three feet from the anchorage or more, depending on each situation. In this case, from the preliminary sample inspection performed by the Owner, it was found that the absence of grease in the tendons started at the connection of the greased sheathing with the seal tube (about one foot from the anchorage). However, due to access reasons, the drilling into the sheathing was performed at about three feet from the anchorage in those cases where the tendons went through the columns. Figs. 11 and 12 illustrate

Fig. 11 - Drilling through slab and tendon sheathing

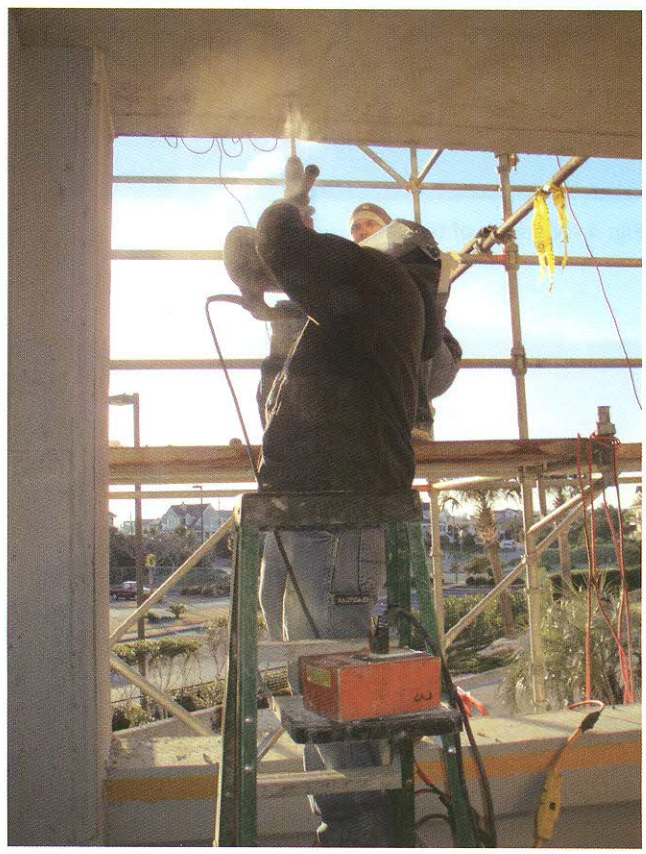

Fig. 12 - Drilling through slab and tendon sheathing

Fig. 13 - Drilled holes into tendon sheathing at balcony

drilling from underneath the slab at a distance of about two feet from the anchorage. Fig. 13 shows the drilled holes; note that the holes may need to be staggered to accommodate all of the tendons in a group for banded tendons. (see the staggered holes behind the column in Fig. 13).

Grease Injection: In slab decks or balconies exposed to aggressive environments, the injection of the annulus between the sheathing and strand takes place from injection ports underneath the slab (see Fig. 14); the space between the strand and wedges at the anchorage serves as a vent. However, there are some cases where it is more practical to perform the injection from the anchorage (Fig. 15). An example is in case of banded tendons crossing at columns, where the points of access into the tendons falls behind the column face. The tendons are very close to each other; this makes it difficult for the GPR to individually locate the tendons and also to use the same location as an injection port (see Fig. 13, behind the column). Despite this difficulty, vent holes should be drilled whenever possible, at the sheathing; otherwise, air can get trapped inside.

The grease injection from the fittings installed at the drilled ports should continue until the grease comes out through the wedges at the anchorages (see Fig.16). At the balconies, all injection ports are located underneath the slab in order to eliminate any subsequent water intrusion through those ports. The GPR scanning and grease injection can be performed from the top and bottom respectively to expedite the production rate of the repair.

Cutting of strand tails and installation of new grease caps at all anchorages repaired: The strand tails should be cut to appropriate length to allow the grease caps to snap properly in place. This will ensure proper encapsulation and prevent any future water intrusion. Cutting devices are readily available in the market that allow fast and proper cutting of the strand tails.

Patching of stressing pockets and injection ports: The patching should be done with a non-shrink grout in order to eliminate development of shrinkage cracks that could provide a potential path for water intrusion. The concrete surface was cleaned and wet prior to the pocket patching.

Fig 14 - Injecting grease from ports located underneath the slab

Fig 15 - Grease injection at anchorages

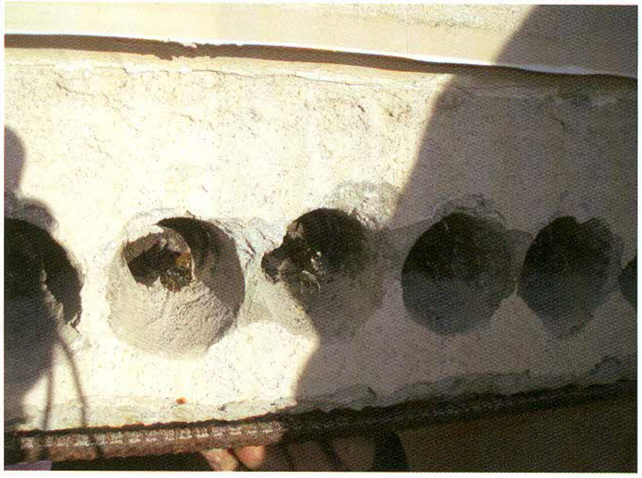

Fig. 16 - Grease excretion through wedges indicating filling of sleeves

5.0 USUAL CHALLENGES

In order to accomplish the repair works, and depending on the extent of the repair, the structure may have to be evacuated for certain period of time. This could result in loss of revenues in addition to the repair cost itself and it needs to be accommodated in the budget. Some of the common challenges in a repair project of this nature are:

Tight schedule, with repairs often required to the exterior and interior of the building.

Weather conditions are sometimes very difficult. Rain and high winds, at times could prevent the field personnel from working on swing stage or scaffolding.

Some banded tendons are difficult to locate due to their actual placement during construction (if tendons are closer than about 2 in., it becomes difficult for the GPR unit to locate the tendons, individually, as it is required for drilling purposes).

Usually there are a few subcontractors working on the interior and exterior of the building at the same time: window contractors, waterproofing contractors, EIFS contractors, carpet contractors, etc.; careful coordination becomes imperative in order to avoid interferences among the different parties involved.

SUMMARY AND CONCLUSIONS

This article illustrates a relatively simple procedure to effectively remediate a construction deficiency that may cause corrosion from water intrusion into the tendons. In some cases, however, it may be difficult to completely stop the corrosion activity that has already started. This could be caused by a number of factors, such as access to certain anchorages. While there is always a way to solve a problem, the cost of the remediation solution may be too high and a more practical approach taken by owners may be to mitigate the problem and delay the deterioration process as much as possible.

The best solution is to take precautions during initial construction and follow the PTI guidance for inspection and installation. Longer tails lengths that prevent proper installation of grease caps should be avoided. Improper filling of annulus between the strand and the seal tube connecting the tendon P.E. sheathing to the anchorages may cause also corrosion activity that could ultimately result in deterioration of significant number of tendons in the structure. The responsibility of a good project relies in all members of the industry: Tendon Manufacturers, General Contractors, Post-tensioning Installers, Inspectors and Engineers. If the industry specifications are followed properly, long term durability problems can be eliminated.

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