Figure 1 – When a structure has post-tensioned floor decks, it is likely to have a post-tensioned roof deck as well. This arrangement can produce rather significant spacing of columns—sometimes 55-65 feet on center, depending on building use. Note the relatively compact section of floor slabs in comparison to some other concrete types.

ABSTRACT
This is the 11th in a series of articles examining various deck types. Among the numerous considerations when selecting a roof system, the type of decking is among the most important. With the variety of decks to be encountered (both new and old), it is incumbent upon roofing experts to be the authority on these matters. This article will explore features of post-tensioned concrete.

This type of deck construction is highly specialized and should be carried out only by skilled professionals experienced in the work. A wealth of related information is available through sources such as The Post-Tensioning Institute, Farmington Hills, MI, and this article does not supplant any such work. Instead, it is intended as an overview of matters likely to be encountered by the practicing roof consultant.

This rather unique form of construction may be encountered where long spans are needed and for occupancies that are uninterrupted by columns. These decks may be found in casinos, and some schools, plaza decks, multistory dwellings, balconies, and parking decks. Practicing consultants may be involved with post-tensioned decks in matters of reroofing, balcony waterproofing, and parking deck rehabilitation. Post-tensioned construction can produce remarkable spacing of columns, often 55-65 feet on center, depending on building use. When a structure has floor decks of this type, it is likely to also have a post-tensioned roof deck (Figure 1), so the practitioner should recognize it as more than just an ordinary concrete deck. Advantages of this configuration are generally recognized as:

• A thinner, more compact deck section, reducing the amount of concrete required
• Reduced steel reinforcing in comparison to some other concrete profiles
• Decreased deck mass (dead load), reducing the size of columns and required footings

In the case of pre-stressed deck types such as structural tees and hollow-core planks, the embedded strands (commonly seven-strand wire) are stressed at the plant and are bonded to the concrete. In post-tensioned work, the strands or tendons will be stressed after the concrete has hardened; hence the name “post-tensioned.” Decks of this type fall into two categories:

1. The bonded category employs steel strands that are collected into light-gauge metal ducts or hollow metal tubes; after tensioning is completed, the void space in the ducts is grouted. This is usually implemented when very high post-tensioning forces are required.
2. On the other hand, unbonded tendons...
Figure 2 – These grouped tendons are situated within a gray plastic sheath; they are greased within to prevent bonding of the steel cable to the concrete. Tendons will be stressed after the concrete has hardened; hence, the name "post-tensioned."

The sequence of construction may go as follows. Formwork is erected and prepared in similar fashion to that of other cast-in-place slabs, and the tendons are arranged across the work surface as specified (Figure 3). Other reinforcing will also be present (i.e., deformed bars, welded wire grid), and it may be situated above or below the stressing tendons (Figure 4). Remember that rebar are greased and individually arranged into a plastic sheath. Figure 2 depicts grouped tendons situated within a gray plastic sheath. This configuration is recognized in most circles as requiring repairs more often (i.e., corrosion, ruptured tendons).

Figure 3 – Concrete formwork in place and loops of the prepared stressing tendons arranged for layout across the work surface.

Figure 4 – Ordinary steel rebar (deformed bars) may be situated above or below the tendons, based on the design intent. The green sheaths depicted are individual post-tensioning strands.
is situated in the tension zone of a section, so ordinary spanning arrangements would have it at the bottom of a section, while a cantilevered balcony would have rebar near the top (above the neutral axis).

A pocket feature through which tendons will emerge is cast at the slab edge. A locking device is then fitted to restrain eventual tensioning stress; there will be some relaxation of the cable stress, and this is anticipated in the design (Figure 5). Concrete is then placed and finished; and following development of adequate strength (often a matter of a few days), tendons are stressed using hydraulic jacking equipment. Figure 6 depicts a hydraulic jacking device positioned to stress a beam-to-column connection; for roof and floor slabs, similar jacking equipment is used, although it is much smaller because only individual stands are tensioned as opposed to cable groups. There will be some relaxation of initial stress, and this is anticipated in the design. After tensioning, cable ends are locked off and cut, and a grease cup is installed and capped to prevent water intrusion (Figure 7). If this is bonded construction (as described above), grout will be injected, and vent tubes are then cut.

Traditionally, the pockets have been closed using cementitious, non-shrink grout; however, modern pre-formed plugs have also been developed for this closure. These also serve to indicate that tendons have been cut to proper length and are ready to be closed. After tensioning has been completed, formwork is then
Figure 8 – Stressing tendons assume a nearly parabolic shape between supports. This is known as drape, defined as the maximum distance between a line connecting the force applied at the end of the slab and the lowest point of tendon sag.

stripped from below and cycled for re-use if appropriate.

When situated into place, stressing tendons assume a parabolic shape between supports. This is known as drape (Figure 8), defined as the maximum distance between a line connecting the force applied at each end of the slab and the lowest point of tendon sag. Drape is highly desirable, as the reinforcement assumes position where it is most needed: the tension zone of concrete (Figure 9). Once the strands are tensioned by hydraulic jacking equipment, the upward drawing of tendons counteracts the load that will eventually be carried. This amount of load offset is usually ~80% of the dead load, although that figure may vary according to design.

It should be evident that mechanically attached roofs are not the optimum selection for decks with this array of embedded strands. While it is possible (at considerable expense) to repair broken tendons in situ, the best course is to select more compatible roof assemblies—those that avoid fastener penetration.

Caution should be exercised—particularly in reroofing where cutting, coring (i.e., new drain openings), or fastening activities are prone to contact the pre-stressing tendons. Just as with utilities, call before you dig. If new drains are to be installed—or for that matter, any penetrations through the deck are required in a reroofing scenario—x-ray or ground-penetrating radar (GPR) techniques can be deployed.

Figure 9 – Drape is desirable, as the reinforcement follows a contour in locations where it is most needed: the tension zone of a concrete section.
Figure 10 – Although such activity will delay roofing production, when revealed, any ruptured tendons should be restored (image courtesy of Restocon Corporation, Tampa, FL).

As outlined above, these decks are relatively compact (in comparison to some other forms of concrete), and encountering the shallow reinforcement is more probable. Sometimes embedded tendons may be corroded or ruptured before the roofing contractor has even started work, and these locations may only be revealed once tear-off is underway. Even though such an occurrence will certainly delay work production, these compromised areas should be restored (Figure 10). New cable can be spliced-on, and hydraulic devices can reintroduce tension to restore load-carrying capacity (Figure 11). Again, this work should be attempted only by skilled and experienced mechanics.

SUMMARY REMARKS

Post-tensioned concrete is a specialty domain, and decks of this type should be reserved for crews having certification.

Figure 11 – New cable can be spliced onto compromised zones, and hydraulic devices can then reintroduce tension. Again, note the relatively thin section (image courtesy of Restocon Corporation, Tampa, FL).
in post-tensioned construction. Even well-seasoned concrete workers may not have the necessary skills required for this specialized field. A variety of roof assemblies couple well to this deck, but those requiring attachment devices should be dismissed in favor of other options. Again, this type of deck can be repaired, and it certainly should be when advanced corrosion, ruptured tendons, or other distresses are encountered. When compromise is revealed, proper repairs should take precedence over the delay in work production.

The well-advised consultant should understand the foregoing topics and not be caught off guard when involved with reroofing, balcony waterproofing, parking deck rehab, and the like. The prudent contractor should be on guard against being blamed for ruptured tendons that are not his/her doing.

REFERENCES
3. “Products and Practice Spotlight; Post Tension Plugs.” Concrete International. Dec 2016, V. 38, No. 12, p. 52.

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NYC Passes Bill to Expedite Wind Turbine Installation Approval on Roofs

A bill passed April 23 by the New York City Council would create guidelines to be drafted by the buildings department to streamline and expedite review and approval of installations of wind turbines on roofs in the city. A complementary bill requires officials to create a wind map showing where the devices would work best. A third bill will require that all city-owned buildings be powered by green energy by 2050.

In many cases, solar panels are more cost-effective as small-scale power generators than wind turbines. (See https://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/9556/Rooftop-Wind-Turbines-Are-They-Worthwhile.aspx.)

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