Construction Concerns: Post-Tensioned Concrete
Article and photos by Gregory Havel
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We are probably more familiar with concrete reinforced with steel reinforcing bars (which is poured into forms at the construction job site) than with pre-stressed concrete (see “Construction Concerns,” February 23, 2009) or post-tensioned concrete.

Photo 1 shows the underside of a poured-in-place reinforced concrete floor-ceiling assembly. This type is often called a “waffle slab.” The beams running in both directions contain steel rebar for strength. The relatively thin slab at the top contains smaller rebar or welded steel wire mesh. The assembly shown in photo 1 is the ceiling of the large apparatus bay in a fire station headquarters, and the floor of the firefighters’ dormitory directly above. The webs of the waffle are on three-foot (0.914 m) centers, and are 16 inches (40.6 cm) deep. Note that in this type of concrete construction, as in pre-stressed concrete, the beams are close together.

Post-tensioned concrete uses tendons (usually ½-inch (12 mm) tempered steel cables with 270,000 pounds per square inch (psi) tensile strength) in addition to rebar to give it strength. The tendons are covered with paper or plastic tubing or wrapping (ducts) so that the concrete will not bond to them. After all of the tendons and rebar are in place, the concrete is poured. After the concrete has cured, tension is applied to the tendons (also called “stressing the tendons” or “jacking the cables”), which compresses the concrete horizontally, gives it strength, and makes it self-supporting. Tendons are usually stressed to about 33,000 psi, but greater stress can be applied for greater strength. The tendons are cut off at both ends, the openings in the edge of the concrete slab are patched, and the forms and falsework are removed from below. The ducts are sometimes filled with epoxy grout after the tendons are stressed before the ends are sealed.
Photo 2 (left) shows part of a building of post-tensioned concrete construction. Note that the beams and columns are widely separated, that the floor-ceiling slab is relatively thin, and that it is flat on both top and bottom.

Photo 3 (below) shows part of the same building, with the metal forms and falsework still in place. Wood forms and falsework may also be used, but these are combustible, especially after becoming coated with form oil.

The row of dark marks on the edges of some of the floor slabs in photo 2 and photo 3 shows the location of the tendons, after they have been stressed, cut to length, and patched with grout. Also note on the corner of the floor slab that the tendons run in one direction only, not in a grid like rebar.

Builders like using post-tensioned concrete because it allows for longer spans, fewer columns, and larger open spaces in the building; faster construction than some other methods; and uses one-fourth to one-third less concrete than waffle slabs or prestressed double-tees. It is used most frequently in high-rise buildings, parking structures, and bridges.

Post-tensioned concrete is used more frequently today than in the past, and its use has increased by 40 percent in the last 10 years.

Post-tensioned concrete presents some hazards to firefighters:

- Until the concrete has cured and the tendons have been stressed, the entire weight of the concrete and reinforcing steel is supported by the forms and falsework. Collapse is nearly certain if there is a fire involving these supports.
- The tendons are made of tempered steel cable that fails when heated to 800°F (427°C), and weakens at lower temperatures. The tendons can whip when cut or broken, causing severe injuries.
- When the ends of tendons are exposed to fire before they have been covered with cement grout, they can weaken and fail quickly.
- Post-tensioned concrete construction has less mass than other types. Reduced mass means less inherent fire resistance.

For detailed information on the materials and methods for this type of construction, visit the Web sites of the Post-Tensioning Institute at www.post-tensioning.org and the Web site of the Portland Cement Association at www.cement.org

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The building under construction in photos 2 and 3 is a block from the Indiana Convention Center in Indianapolis, Indiana, and should be completed before FDIC 2010.

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