Contraction Joints for Residential Post-Tensioned Slabs

by Harvey Haynes and Kenneth B. Bondy

Contraction joints are generally not installed in residential post-tensioned (PT) slabs-on-ground—yet they should be. It is common to find random cracks in PT slabs because cracks can develop before the post-tensioning is applied. Thermal contraction and drying shrinkage affect PT slabs in the same manner as non-PT slabs, which typically do receive contraction joints.

There are two likely explanations for the lack of joints in PT slabs. First, many designers are aware that post-tensioning is used in warehouse slabs to eliminate contraction and construction joints and thus reduce forklift maintenance. Second, many designers have the perception that PT slabs should not have cracks, so joints are unnecessary.

In the arena of construction defect litigation, some owners claim that cracks in a residential PT slab comprise a construction defect. If cracks are present, they assume that a design or construction problem occurred. Some engineers also apparently believe that a cracked section of a concrete slab-on-ground cannot function properly as a post-tensioned member. These technical issues have been addressed by Bondy[1] and will be discussed herein.

PTI Recommendations

As noted in PTI DC10.1-08, "Design of Post-Tensioned Slabs-on-Ground,"[2] contraction joints are permitted in slabs-on-ground. This document states: "Control joints, which are weakened planes formed by tooling, sawcuts, or mechanical devices, can be used effectively to attract and conceal restraint-to-shortening cracks in slabs-on-ground." This document has significance, as it is the referenced PT slab design document in ACI 332-14, "Residential Code Requirements for Structural Concrete and Commentary."[3]

Contraction joints in PT slabs are desirable because random cracks will be eliminated or substantially mitigated, thus minimizing aesthetic concerns. Further, joints shown on construction documents convey design intent and acceptability from a structural standpoint.

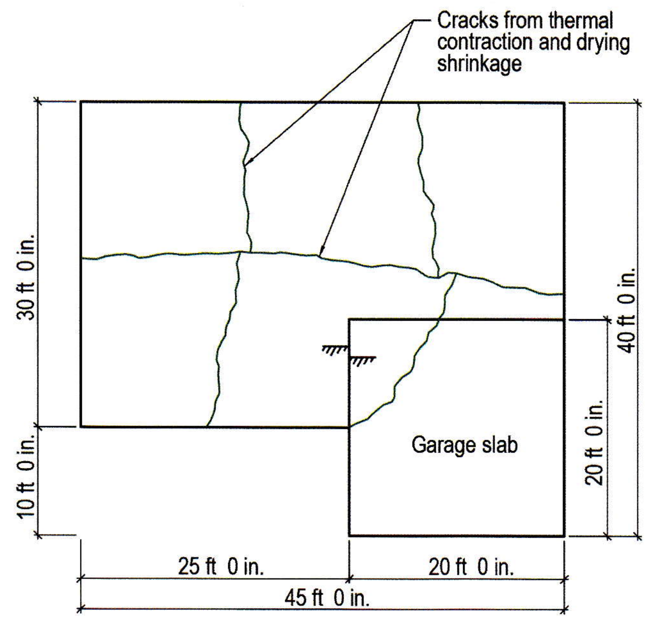

Fig. 1: Representative cracking pattern in PT slab-on-ground having a uniform thickness of 10 in. (250 mm) (Note: 1 ft = 0.3 m)

Contraction Joints in PT Slabs

As previously noted, Bondy[1] discussed the structural influence of thermal contraction and drying shrinkage cracks on PT slabs. Figure 1 shows representative random cracks in a PT slab having a uniform thickness. The maximum moment in PT slabs-on-ground usually occurs from center lift conditions, in which shrinkage of the soil by drying can leave the concrete slab unsupported at the edges over a distance e_m (Fig. 2). The maximum moment is approximately located at distance β from the edge.

$\beta = (1/12)(E_{cr}\, I/E_s)^{1/4}$ in U.S. Customary units

or

$\beta = (1/1000)(E_{cr}\, I/E_s)^{1/4}$ in SI units

where β is the distance from the slab edge to the location of

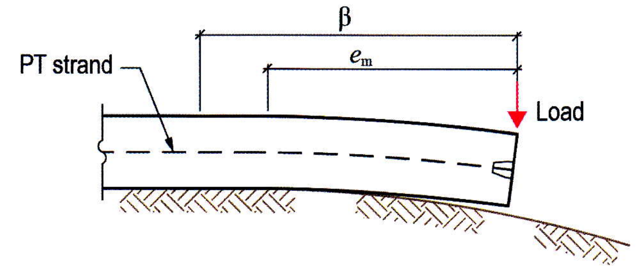

Fig. 2: Center lift condition, where the soil is dry at the slab edges, causing a portion of the slab to be cantilevered the distance e_m. Maximum moment location is approximately at β

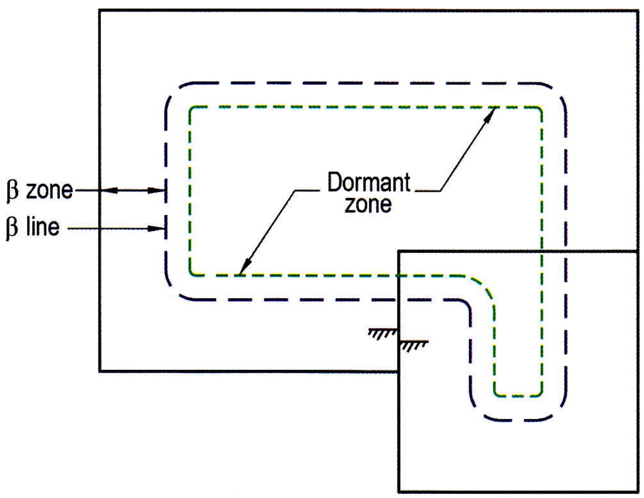

Fig. 3: The β-line is the approximate location of maximum moment. The dormant zone is the area of small moments and shears

maximum moment, in ft or m; E_{cr} is the long-term or creep modulus of elasticity of concrete, in psi or MPa; E_s is the modulus of elasticity of soil, in psi or MPa; and I is the gross moment of inertia of the slab perpendicular to the direction of bending, in in.^{4} or mm^4.

Later documents provide practical recommendations for the moduli values. "Design and Construction of Post-Tensioned Slabs-on-Ground"[4] states that E_s can be estimated as 1000 psi (7 MPa) if the modulus of elasticity of the clay soil is not known. PTI DC10.1-08 further states that E_{cr} may be taken as 1,500,000 psi (10,000 MPa) unless more refined calculations are used. In general, β ranges from 6 to 10 ft (1.8 to 3 m). For example, a slab with a uniform thickness of 10 in. and widths of 30 and 60 ft (9 and 18 m) will have β values of 6.8 and 8.1 ft (2.1 and 2.5 m), respectively.

The bending moment increases from zero at the slab edge to maximum at the β-line (Fig. 3) and then decreases rapidly over a short distance. The area inboard of the β-line is the dormant zone and is a region of low moments and shears.

Thermal and drying shrinkage cracks develop perpendicular to the maximum moment, so the presence of these cracks is innocuous. To mitigate the tendency for these cracks, it is common for designers to lay out joints at a

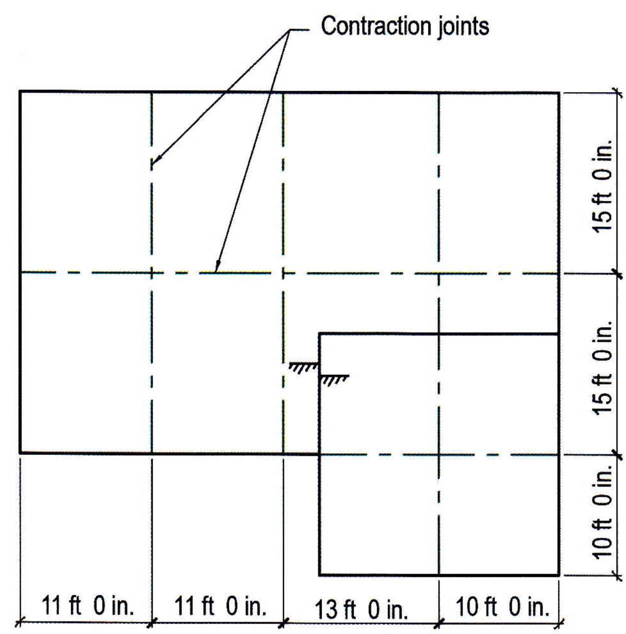

Fig. 4: Contraction joint layout for a PT slab (Note: 1 ft = 0.3 m)

spacing of 12 to 15 ft (3.7 to 4.6 m), starting about 10 to 12 ft (3 to 3.7 m) from the edge of the slab, regardless of the slab thickness. The maximum spacing of joints in PT slabs is the designer's prerogative—any spacing of joints will assist in minimizing or mitigating random cracks. Further, the aspect ratio of the panel defined by the joints is not as critical as it is for non-PT slabs. It is acceptable, for example, to use a joint layout that results in panels with aspect ratios exceeding 1.5.

The design professional should determine the joint layout and show the joints on the construction drawings. Figure 4 provides an example of a joint layout. For aesthetics, joints in the garage area shown in the example would be expected to intersect the slab at midpoint locations. The interior slab areas will likely receive floor coverings, so joints in the interior slab areas do not need to be straight lines parallel to the slab edges.

Installation methods

Scoring, installing inserts, and making saw cuts are the standard methods used to produce contraction joints. Scoring is the preferred method for small slabs, installing polymer inserts for medium-sized slabs, and saw cutting for medium to large slabs. While saw cutting could be used for residential PT slabs, it introduces the risk of nicking the slab tendons.

Residential slabs can be considered medium-sized slabs, so installing polymer inserts in fresh concrete is the preferred method. Two insert types are generally available: rigid strips[5] or flexible tape[6]. (Fig. 5). The latter method is new to the industry and holds promise as a significant advancement.

Summary

Currently, contraction joints are not commonly used in residential PT slabs, even though joints can minimize random

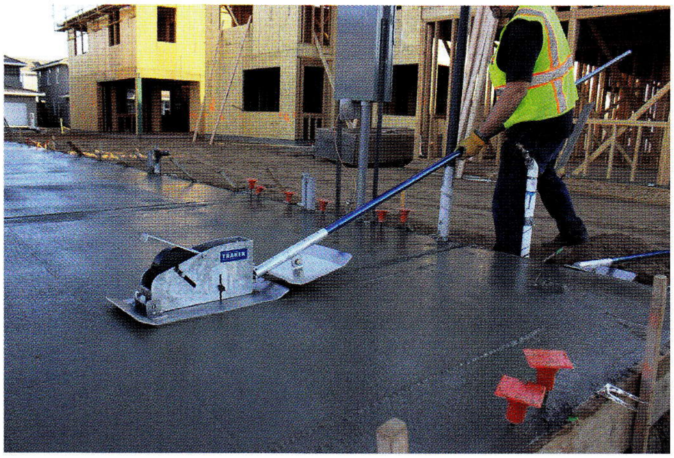

Fig. 5: This manually operated tool is used to embed a polymer tape into fresh concrete. The tape creates a stress concentration in the hardened concrete, typically resulting in a relatively straight crack that opens as the concrete shrinks *(photo courtesy of Aaron Hilbert LLC)*

cracking. PTI permits the use of contraction joints in PT slabs-on-ground for residential foundations, as joints will not detrimentally affect the structural behavior of the slab. It is essential, however, that a design professional determines the joint locations and provides the joint layout on the construction drawings. A defined and rational joint pattern will provide aesthetic benefits to the designer as well as the contractor and the owner.

References

1. Bondy, K., "Cracking in Ground-Supported Post-Tensioned Slabs on Expansive Soils," PTI Technical Notes, No. 6, Post-Tensioning Institute, Farmington Hills, MI, Aug. 1995, 6 pp.

2. PTI DC10.1-08, "Design of Post-Tensioned Slabs-on-Ground," third edition with 2008 Supplement, Post-Tensioning Institute, Farmington Hills, MI, 2008, 156 pp.

3. ACI Committee 332, "Residential Code Requirements for Structural Concrete (ACI 332-14) and Commentary," American Concrete Institute, Farmington Hills, MI, 2014, 54 pp.

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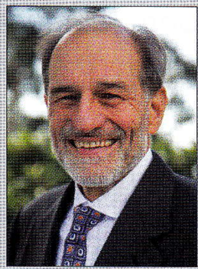
5. Superior Profiles, Inc., 2014, www.superiorprofiles.com.

6. Wood, G., "New Tool for Slab Joints Reduces Concrete Cracking," *Concrete Contractor*, Jan. 2020, pp. 14-16.

Selected for reader interest by the editors.



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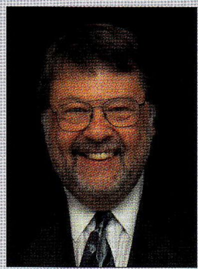

ACI Honorary Member **Kenneth B. Bondy** specialized in design and construction of post-tensioned concrete building structures for over 50 years. Now retired, he was a member of ACI Committees 132, Responsibility in Concrete Construction; 318, Structural Concrete Building Code; and 332, Residential Concrete Work, and Joint ACI-ASCE Committee 423, Prestressed Concrete. He is a Post-Tensioning Institute "Legend of Post-Tensioning" as well as an Honorary Lifetime Member and Fellow. He received his BS and MS in civil engineering in 1963 and 1964, respectively, from the University of California, Los Angeles, Los Angeles, CA. He is a licensed civil and structural engineer in California and has been licensed in many other states.