

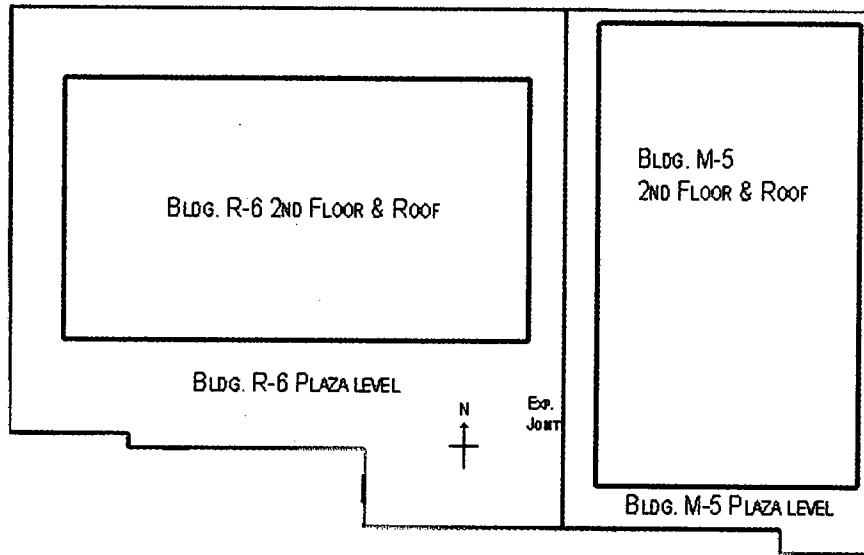
**Use of Shrinkage-Compensating Concrete in Post-Tensioned Buildings:
*Type K Stands the Test of Time***

By Kenneth B. Bondy, SE, FACI

Restraint to shortening (RTS) cracking is a major problem facing designers of post-tensioned concrete buildings. Typical solutions to mitigate RTS cracking have included joinery details (primarily expansion joints and pour strips) and added reinforcement.

Another proven method for solving RTS problems has been used for over 40 years, and deserves additional recognition. Shrinkage-compensating concrete has been successfully used to cast large, jointless elevated slabs in post-tensioned concrete structures since the 1960s. Made with ASTM C845 Type K cement, the concrete expands slightly during the first seven days of curing, after which it undergoes a normal amount of drying shrinkage, for net volume change closely approaching zero. This article presents a case study where shrinkage-compensating concrete (KSC) was used to solve a difficult RTS problem in two post-tensioned concrete buildings, built more than 40 years ago and still performing well today.

In 1968 the TRW Corporation (now Northrop-Grumman) added two new buildings to its complex in Redondo Beach, CA, one for manufacturing (called M5), the other for research (R6). At the time, I was employed by Atlas Prestressing Corp. in Southern California. We provided consulting services for the design of the post-tensioned floor system to the Architect/Engineer Albert C. Martin & Associates (now A.C. Martin Partners), and furnished and installed the post-tensioning tendons and nonprestressed reinforcing steel for both buildings for the general contractor, Swinerton & Walberg. I was heavily involved in both the design and construction of these buildings.



Buildings M5 and R6 (plan view)

Originally designed for sensitive research and manufacturing equipment, these two buildings, each with a footprint in excess of 72,000 sf, required elevated concrete decks with no control joints or pour strips. Shrinkage-compensating concrete was successfully used to cast all floor members. The buildings continue to perform well more than 40 years later. (Illustration courtesy of CTS Cement Mfg.)

Each building has three stories, a large first floor plaza level, a second floor, and a roof. The second floors and roofs of the buildings are identical in plan dimension, each 199 ft. x 363 ft. The first floors of each building are adjacent, separated by an expansion joint, and orthogonal dimensions are very large: for M5 422 ft. x 243 ft.; for R6 439 ft. x 407 ft. All construction was cast-in-place post-tensioned concrete with unbonded tendons. Column spacing was large, with typical bay sizes of 40 ft. x 64 ft. Floor system framing was a one-way slab (shallow pan joists in R6 for extra stiffness) spanning between beams located on and midway between column lines. The intermediate beam was supported by a girder spanning between columns. Seismic framing for both buildings was provided by moment-resistant beam-column frames in both directions.

Aside from the large plan dimensions, these buildings presented major challenges to the mitigation of RTS cracking:

- Other than the joint separating the two Plaza Levels, no other expansion joints were permitted by the owner.
- Temporary separation joints, such as pourstrips, were ruled out by the contractor because of the difficulty of passing them through heavily reinforced beams and girders.
- Axial prestress compression was high, slightly above 300 psi in each direction, thus aggravating the effects of axial shortening.

- Lightweight concrete was used in the floor systems, further increasing the effects of axial shortening and creep.
- Columns below the Plaza level were large (37" square with 16-#14 vertical bars) providing significant restraint to floor shortening.

Considering these difficult conditions, a decision was made by the designers to use Type K shrinkage-compensating concrete for *all* floor members. For the short period of time after placement, when shrinkage-compensating concrete expands, growth of the floor system is restrained by connected members. This restraint generates moment and shear forces in the floor system and in the restraining members. However these initial restraint forces are minimal, since the expansion occurs when the concrete is young and the stiffness of the restraining members is not fully developed. After expansion, when normal drying shrinkage begins, restraint forces **decrease** with time, approaching zero as the magnitude of the shrinkage approaches the initial expansion. This mechanism permits the elimination of, or greatly increased spacing between, expansion joints and pourstrips.

This process was highly successful in the TRW buildings. Recently, more than forty years after construction, I had the opportunity to observe the buildings, in the presence of Northrop-Grumman facilities personnel. The structural condition of the observable portions of the floor system and columns was excellent, virtually crack-free after four decades of continuous service. According to Jimmy Guerrero, P.E., Facilities Project Manager, and Phillip Yee, Facilities Risk Manager, both Northrop-Grumman employees who have worked onsite at this facility for years, the structural performance of the buildings has been excellent and they have required no unusual maintenance or repairs over their entire service life. These buildings are a testimonial to the use of shrinkage-compensating concrete in post-tensioned concrete buildings.



South Elevation Building R6 – Looking Down 439 ft. Length at Plaza Level

Kenneth B. Bondy, SE, FACI, has specialized in the design and construction of concrete building structures, mostly post-tensioned, for more than 45 years. He is the current President of the Post-Tensioning Institute (PTI) and was, in 2005, inducted into the PTI Hall of Fame, "Legends of Post-Tensioning". He serves on numerous ACI committees including Committee 318 (Standard Building Code), Committee 423 (Prestressed Concrete), the Technical Activities Committee (TAC), and the Committee on Responsibility in Concrete Design and Construction. He has been widely published on a variety of design issues concerning concrete and post-tensioning. Mr. Bondy can be reached via www.kenbondy.com.