Changing Concrete Mix Eliminates Parking Garage Cracks

By Dave Flax

In the early 1990s John Wayne Airport in Orange County, Calif. was continuing its growth into a major airport. With that growth came the need for a parking structure.

The decision was made to design a large parking garage for almost 4,000 cars, but to construct only half of it immediately. The rest would be constructed in about five years, when the volume of cars required it. In 1993, the two lower decks of the garage were built. It was a standard design with cast-in-place 5000 psi, post-tensioned concrete. It didn't take long for the age-old problem of cracking to begin.

The Problem

Only six months after completion, the nearly 75,000 linear feet of cracks had to be addressed. That's more than 14 miles of cracks. One of the project managers said, "You can't walk six feet without seeing another crack." The cracks were routed out and filled with flexible joint filler. Photo 1, which was taken after the garage, had been in service for 10 years shows that some of the joint filler was still in place, but that much of it was gone. Where the joint filler has come out, the routed out vee serves as a funnel to accumulate water and even more water goes into the crack than if the cracks hadn't been "repaired." This process after just six months of operation cost the owner more than $500,000 and the owner allocated another $500,000 for future repairs.

There has also been some epoxy crack injection as shown in photo 2, which is an excellent way to repair cracks permanently. But at $30 to $60 per linear foot, the cost to fix all the cracks this way was prohibitive.

Photo 3 shows the underside of a deck complete with inch long stalactites, which were caused by water going through the cracks and leaching the calcium salts out of the concrete. These salts quickly damage the paint on parked cars.

The Solution

The volume of cars continued to grow so the upper two decks (more than 700,000 square feet) were constructed in 1998. The design team was instructed to do something to eliminate the cracks. They used Type K, also known as Shrinkage-Compensating Concrete, instead of portland concrete.

Everything else stayed substantially the same. The same general contractor performed the work using the same ready mix supplier, post-tensioning and 5,000 psi concrete. The major difference between the two designs was the use of Type K. Even after seven years of service the structure is 100 percent crack free.

The Type K Concrete was made by simply replacing some of the portland cement with a calcium sulfo-aluminate cement component while leaving the rest of the mix the same.

Photos 4 and 5 show the bottom and top of a deck after seven years. There are no cracks anywhere and remember that the cracks in the lower Portland concrete decks were occurring within months. These are not selective pictures. There actually are no cracks in the Type K Concrete decks that are seven years old.


Photo 1

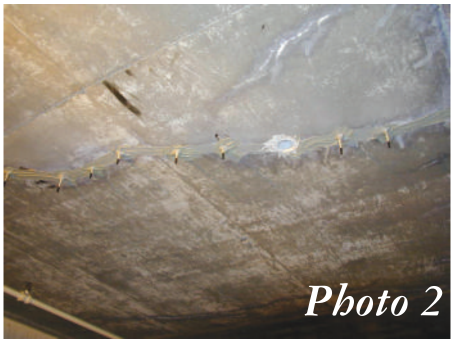
Photo 2

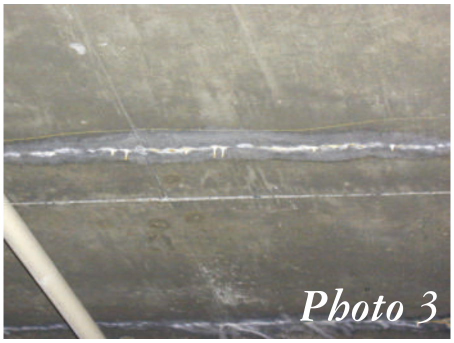
Photo 3


Photo 4


Photo 5

How Does It Work?

For the first seven days after placement, the Type K Concrete will expand slightly. Most of the potential expansion is restrained by the reinforcement and post-tensioning. This restraint puts the reinforcement into tension and the concrete into compression, which is ideal, because that is how these materials work best.

After seven days of wet curing, the concrete dries and it shrinks the little bit that it had expanded and relieves the stresses in the reinforcement and concrete. In time the concrete ends up the same size as when it was placed and in a neutral stress condition. As stated in section 1.2 of ACI 223-98 Standard Practice for the Use of Shrinkage-Compensating Concrete: "….expansion will induce tension in the reinforcement and compression in the concrete. On subsequent drying, the shrinkage merely relieves the expansive strains…" Figure 1 depicts how this mechanism works.

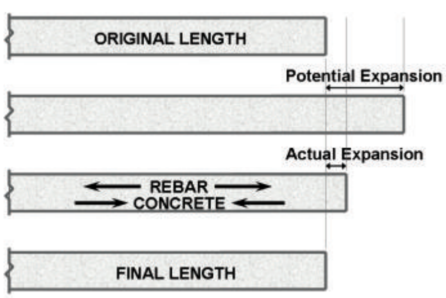

Figure 1

Other Maintenance Benefits

Most concrete is placed at about .45 to .50 water to cement ratio (w/c), but portland cement only needs a .25 w/c for full hydration. The rest of the water, known as water of convenience, is just there to help the contractor place the concrete. All that excess water has to come back out of the concrete. One cubic yard of a typical 5000 psi portland concrete mix with a .50 w/c has an extra 21/2 cubic feet of water. There are only 27 cubic feet in a cubic yard and 21/2 of them must come out as the slab dries. As the 21/2 cubic feet of water leaves, the slab shrinks and cracks. But Type K concrete requires a .38 w/c for full hydration, so there is less excess water to leave the slab and cause shrinkage and cracking.

Most of that excess water leaves portland concrete by coming to the surface as bleed water, which creates another problem. That bleed water brings fines and laitance to the surface and raises the w/c at the surface. All this lowers the ability of the surface to withstand wear. Per section 2.5.7 of ACI 223-98, with Type K concrete the "….abrasion resistance is 30 to 40 percent higher than portland cement concrete." Look at photo 5. Even the very rough swirl finish, shows no wear after seven years.

The bleed water gets to the surface by creating bleed water channels. The problem is that these channels later serve to let water and chemicals back into the concrete. While corrosion of the steel isn't a huge problem in Southern California, it is a severe problem in many areas of the country, particularly in areas where road salts are used. Without the bleed water channels and without all the cracks to give the water and salt easy access to the steel, corrosion resistance is improved dramatically.

Job requirements were for 3500 psi in three days to be able to stress the cables. The Type K Concrete consistently achieved 3700 psi in two days, which allowed the cables to be stressed a day sooner. Average 28-day strengths for the entire job were 7800 psi.

Cost Savings

The additional cost for the Type K concrete amounted to only a small percentage of the total construction cost. The owner quickly opted for the Type K solution after offsetting the small additional initial cost against the savings in maintenance costs over the life of the garage.

Conclusions

Type K Concrete eliminates, or at the very least dramatically reduces, cracking.

Type K Concrete greatly improves the resistance to corrosion.

Type K Concrete reduces surface wear by 30 percent to 40 percent.

Type K Concrete has withstood the test of time. This garage for seven years, but many garages with Type K are more than 30 years old.

Type K Concrete slightly raises the initial cost, but significantly reduces the life-cycle cost. **CM**

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