The Big Dig… The Big Embarrassment

One Engineer's Opinion

By Craig E. Barnes, P.E., SECB

Were structural engineers shocked and perhaps surprised when national news reported the failure of the Boston's Central Artery (Big Dig) tunnel support system, allowing a heavy concrete ceiling panel to fall crushing two occupants in a vehicle below? Given the history of the tunnel and its many problems portrayed over and over again in local and national media, perhaps you were not. My feeling was one of great disappointment; disappointment that within the design and construction bureaucracy of the Big Dig, an experienced structural engineer was perhaps disregarded.

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Within the second day of the calamity, photographs aired on television and in newsprint showing an intact epoxy-set anchor having been extracted from the concrete substrate. There is more than likely a heart sick engineer who, on seeing the photos, lamented, "why didn't I speak up or protest more loudly?"

Within a week of the occurrence, I was interviewed by Channel 7 in Boston for one of the endless pieces that the local news was putting out on the tunnel. Channel 7 professed to be interested in learning about these panels secured by "glue". I went to the interview armed with information on cast-in-place anchors and inserts, and post installed anchors. I was prepared to discuss redundancy versus safety factor concepts and, from a seven year stint on ACI 3-18, prepared to discuss the code process and how post installation anchors had made their way into the ACI code. I was also prepared to discuss why epoxy anchors were not part of the ACI code post installation anchor criteria.

As the pre-taped session ended, the interviewer asked what was my reaction and how did I feel when I first became aware of the tragedy. I tried to explain to the interviewer that my overall reaction was analytical. Engineers are often accused of being too analytical, and perhaps it is true. Was the problem simply an installation issue, was it a question of a heavy panel being swapped for a light panel, were there environmental factors which may have contributed to a fatigue problem? Those are the items that filtered slowly through my mind as I contemplated the tragedy. As to emotions, which news people love to hear, I was disappointed that the system had failed and saddened at the loss of life. There are now investigations, discoveries, interviews, and depositions, all of which will more than likely do very little to improve the efficiency of the system. How embarrassing to have the Governor of the Commonwealth of Massachusetts standing in front of the TV cameras using a flair pen on a poster board describing how an epoxy anchor works. My disappointment is that this situation grew to a point such that the Governor had to explain what an epoxy anchor is. To the experienced structural engineer, the process of anchorage is so basic that the Governor need never know how an epoxy anchor works or even that it exists.

Anchor that is being installed on the project. Image courtesy of Hilti, Inc.

> "Was the problem simply an installation issue, was it a question of a heavy panel being swapped for a light panel, were there environmental factors which may have contributed to a fatigue problem**?**"

I assume for this discussion that the design issues are not at question. We are left then with installation. Why do you suppose that manufacturers of epoxy anchors have, in their literature, photographs of the installation process either showing a horizontal surface below or a vertical surface? Have you ever seen a manufacturer touting their epoxy anchor being installed in an overhead position? If you are asking what could go wrong, you are still working on becoming an experienced structural engineer. The following commentary is then from an experienced structural engineer to the inexperienced.

When epoxy anchors first appeared on the scene, glass capsules containing part A and B were a standard installation process. They worked great in a vertical downward position. In the horizontal position, they worked; however, there was the loss of epoxy unless really strict procedures were employed to contain the epoxy in the hole. We tried the overhead anchor and, working with the manufacturers, tried a variety of ways to keep the epoxy in place (caulking, neoprene seals, even cardboard pieces starred to insert the rod). None of the techniques worked sufficiently to give us a sense of comfort, so we have abandoned the use of capsules overhead. Paste epoxies were introduced shortly thereafter and progressed quickly from two cans to one can with a component, and finally to the self-mixing injection nozzles.

Using epoxy anchors in horizontal and downward vertical positions allowed us to begin concentrating on the installation process: how clean was the hole, what was the diameter of the hole, what was the moisture and temperature condition of the hole's surface? We were observing the workmen in the field, driven by the need for production. We watched holes being drilled that weren't quite deep enough or quite clean enough, and tried overcompensating with a larger diameter hole; more epoxy was better, correct? Then we learned about epoxy flow. Epoxies are plastic; therefore, their properties change with temperature. We learned that epoxy anchors under a sustained load were not the best under many circumstances, and all this without even trying the overhead installation. Then there is that whole matter of drilling and hitting an obstruction. We tried a variety

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of ways of building-in redundancy — such as: if we need three anchors, we'll place four. That way if one is lost during the installation process, we're not all that concerned. When conditions permit, we use a template. Allow the anchors to be installed, then follow with a cardboard template that is used to drill matching holes in the setting plate.

What happens when an obstruction is encountered? Can it be burned through, cored through, drilled through? There are some excellent small cores and chopping bits that are available today which have made that decision somewhat easier. However, you had better be sure that you are not affecting the overall structural capacity when you need to interrupt a reinforcing rod.

Now, let's talk about an overhead situation. For those of you involved in façade inspections with the use of binoculars, I ask how long you can stand with your head tilted in one position before you begin to rush what you're observing, or find a way to brace yourself both for steadiness and comfort? Picture the workman holding the drill, trying to make an anchor installation overhead, and doing this for a six-hour production day. Wouldn't you quickly be writing into your specification that the installation would require a platform on rollers, so the workmen could lie horizontally? Before the Heper Vac, where do you think the dust and the residue from the drilling operation went? Debris fell directly into the worker's eyes, so we provided goggles and breathing masks — more cumbersome equipment to impede the process. Cleaning the hole is just one more problem for the contractor. For the workman, imagine this: *The vacuum is on the ground, I'm way up here, easier for me to use the hand squeeze air bulb. The air bulb fell off the platform. I'll use the wire brush. Oops, the boss forgot to give me the wire brush, but the hole looks pretty clean in any case.*

The engineer observing these particular issues began requiring more and more testing of the installed product. Perhaps, testing every anchor to a proof load, and testing some random anchors to failure. The introduction of the undercut anchor eased somewhat the epoxy anchor dilemma. At least we don't have to rely on the "glue".

The young engineer can become an experienced engineer in short order. The next time you are on an anchor installation job, try installing some anchors.

Oh… the Channel 7 interview?...too technical to broadcast.▪

Craig E. Barnes, P.E., S.E., of CBI Consulting Inc., designs, coordinates, and manages structural and civil engineering projects throughout New England. Mr. Barnes has designed governmental, educational, industrial and residential projects utilizing all types of construction and materials. Craig is a current member of the STRUCTURE® Editorial Board.