

Blasting Concrete at Box Canyon Dam

by Wes Bender

In a recent issue of *The Primer* we discussed various uses of explosives, including the use of detonating cord to blast concrete. In that particular article, we blasted portions of a concrete breakwater into very small pieces and projected them out into the ocean. In this issue, we'll take a look at a project to section off concrete and remove it in blocks. For reasons that will become apparent, I'm not disclosing contractor names.

Back in 1984 and 1985, I worked on a project near Mt. Shasta to install a powerhouse at the base of Box Canyon Dam. Initially, I was working with the blasting subcontractor and was involved mainly in vibration monitoring with a little blast design mixed in to help control vibration levels. During slack periods on that job, I had a chance to go over the plans and specifications and noted that approximately 1700 cubic yards of concrete had to be removed from the face of the dam. Blasting had been precluded by the design engineers.

I indicated to the project manager for the prime contractor that it would be far cheaper and quicker to remove the concrete with explosives, but he said that they were going to use hydraulic splitters and had the issue under control.

After the rock blasting was complete and the subcontractor and I had been gone from the project for several months, I got a call from the prime contractor asking if I could come up and further pursue the issue of blasting the concrete. It seems that the splitters weren't getting the job done. The blasting subcontractor and I had both had rather strained relations with the prime (the blasting subcontractor said he wouldn't go back under any terms), but I agreed to give it a try.

Box Canyon Dam spans a narrow canyon and impounds Lake Siskiyou, the headwaters of the Sacramento River. Because all demolition concrete had to be removed from the canyon below the dam, I envisioned carving it into blocks, each with a grouted-in eye bolt, and hoisting each block out of the canyon. In using detonating cord to section concrete you do not use a conventional powder factor. Instead of pounds per cubic yard, you measure explosives by the number of grains of pentaerythritol tetranitrate (PETN) per square foot of sheared area. I felt that 100 - 200 grains per square foot (gr/sq ft) would do the job and laid out a program of four test shots with a complete cleanup and inspection following each shot. Crane capacity limited block size to 2-3 cubic yards. Because the California Division of Safety of Dams was not familiar with me or my capabilities, I asked Lew Oriard to visit the project site and give my scheme his blessing. Lew pointed out to them that it wasn't practical to use specific vibration limits in this type of work, however he did recommend that we continue to monitor vibration, but at a distance of 50 feet from each blast.

Side Note: It should be pointed out that vibration monitoring under these conditions is still useful. You are trying to minimize cracking in the remaining concrete and as you start to notice minor cracking you can compare the vibration levels when that occurs. The seismograph records become a yardstick that you may be able to use to determine when you are approaching your limits. I have used the same procedure blasting near high pressure petroleum pipelines where we wanted to prevent fractures from extending past a point midway to the pipe.

We received approval to proceed under the close scrutiny of the Division of Safety of Dams. The prime contractor (with his usual disregard for pre-approved procedures) opted to drill out only two test shots instead of the required four, hoping to accelerate the process. The owner's engineer and I prevailed upon the driller to add more test shot holes. To make matters worse, the prime had delayed long enough before contacting me that he now had iron workers starting to put rebar in for the powerhouse below us. This meant we couldn't load or shoot until they went home at 3:30 in the afternoon.

The opening triangular-shaped test shot (shaped like a pyramid, turned slightly more than 90 degrees from vertical) consisted of a total of 12 perimeter holes on 18" centers. Using 101 gr/sq ft, and with the three surfaces shot 35 ms apart, the shot failed to propagate a crack around the perimeter. The holes were washed and inspected. They were then reloaded for the second shot at 149 gr/sq ft. Sides were again shot 35 ms apart. We washed down and inspected. Still no cracks. Reloaded test shot three at 277 gr/sq ft, with sides still delayed 35 ms apart. **STILL NO CRACKS**, good or bad. The engineer encouraged me to double the amount of explosives in order to get results a little quicker. After inspecting the holes carefully, I instructed the driller to add sufficient holes to bring spacing down to 9".

The next day we loaded test shot four (with the tighter spacing) at 500 gr/sq ft. We retained the delay between sides of 35 ms. This time we got results alright, but not exactly what we wanted. The concrete was gone, along with the eye-bolt and a good chunk of the cable. At least, we now had a void toward which the remaining blocks could shift. After washing down, the concrete remaining in place was found to be in good shape. The owner's engineer and the CA Div of Safety of Dams were happy because we were now removing concrete and we weren't causing any damage to their dam. Test shot five was also loaded at 500 gr/sq ft with 35 ms delay between sides. It too resulted in concrete being thrown violently down the canyon. The remaining concrete was intact except for a piece missing between the upper right corner and a nearby vertical construction joint. This was part of the next shot volume and was noted, but not deemed to be of significance.

For test shot six, I reduced the loading to 438 gr/sq ft, but retained the delays. A portion nearest the void was shot first, followed by the top and bottom holes on the same delay and the opposite end shot last. The results were what we wanted. The block could be lifted from the canyon with the crane. We did a couple of more test shots and a couple of concrete trimming shots and the CA Div of Safety of Dams gave their approval to proceed with the process. I retired to the motel to write it all up.

There were only two ways you could get in and out of the canyon, via crane and basket or by way of a series of wooden ladders fastened to the canyon wall. We always had some explosives left over and, because the contractor sent the crane operator home at 3:30 or earlier, we had to pack unused explosives out on our backs. Safety is paramount in this business and, if we had had an accident, there was no way to evacuate the injured.

In my report to the project engineers and the prime contractor, I recommended that we proceed, but with several conditions, foremost of which was that the crane operator stay on duty until all explosives were removed from the canyon daily. (The only approved magazine site was above the canyon behind the construction yard.) The prime wanted me to continue with the blasting but would not agree to keep the crane operator beyond 3:30 for any reason. He indicated that he was sure I could find a place to store the explosives. The inference was that I could store them in a gallery inside the dam. Obviously, I wasn't going to do that, so we reached a mutual agreement that he could find someone else to oversee the work. He then tried to get the previous blasting contractor to come do it using my process, but to no avail. After two weeks, I got a call from the prime saying he would agree to the conditions, but by that time I was committed to extensive consulting for a project near San Diego. Eventually someone did the concrete blasting at Box Canyon Dam. I'd rather not disclose who did the work because I don't know what provisions for explosives storage they used or what other "shortcuts" may have been taken in the process. Before the project was complete, however, the prime contractor received several major citations over safety issues and they suffered one fatality. It turns out that the crane used to lower men and equipment into the canyon had no "dead man" controls. In another instance, a small shot was loaded, but then wasn't detonated for a week or so. All the while men were working in the area near the shot. The CalOSHA District Manager, after citing the contractor, had me go up and detonate it on a weekend. I suspect that particular contractor is no longer in business.

This was one of my first concrete shearing attempts. On hindsight, and following other projects where I've removed concrete with detonating cord, it would have been far better to have eliminated the delays early in the testing process. That would have allowed us to reduce the explosives loads. I initially felt delaying the various sides was advisable, but I've learned since that massive concrete can take a lot of compressive force without suffering ill effects. In any case, always approach the process carefully and always include test blasts.