EARLY HISTORY OF MASS CONCRETE

Dr. Roy W. Carlson was a giant in the field of mass concrete for large concrete dams. His pioneering work on stress meters, low-heat cements, and mathematical models for concrete had a tremendous influence in the field. Here he recollects his first works in the field.

Not much was known about internal heating of concrete before 1925. In that year the Stevenson Creek Experimental Dam was built and internal temperatures were observed. This dam was constructed in a steep canyon such that the reservoir of a dam 60 feet high was only about 100 yards long. If the dam were to fail, there would be no damage from the water rushing out of the reservoir. The dam was 7.5-feet thick at the base and two feet at the crest. When the reservoir was filled, cracks appeared which could not have occurred unless there was tensile stress already in the concrete before the filling.

About a year later, an Ambuersen Dam was being constructed in Mexico. The buttresses of this dam were about five feet thick at the base and more than 100 feet long. After only a few lifts had been cast, vertical cracks appeared, first at the mill length then at the quarter points and even some others. It was believed at that time that the chemistry of cements caused shrinkage of concrete, more or less depending upon the composition of the cement. In this case, Riverside cement was used and it was blamed for the cracking. The chief Chemist of Riverside had read the report on Stevenson Creek so he knew that I had measured the internal temperatures in that dam. When he came to see me at my laboratory in Los Angeles, the first thing he said was "Could the cracks in the Rodrigues Dam have been caused by temperature changes". I suggested that the way to find out was to measure the internal temperatures of Rodrigues and analyze them. I made some simple thermometers by winding enameled copper wire on bakelite spools and insulating the coils by dipping in hot tar. The thermometers were shipped to Engineer Frederico Barona of the Government of Mexico and he had then embedded in the concrete of the dam. The temperature rose to well over 100 degrees F and then decreased after a few days. By making rather rash assumptions, the tensile stress was computed and found to be over 300 psi. We assumed that the stress was zero when the temperature was a maximum and the foundation restraint was 100 per cent. Our results convinced the authorities that the cracks were due to internal heating and the Riverside Cement Company was absolved of blame.

In 1931, research was begun at U.C. Berkeley on cement for the Hoover Dam. This dam was to be almost double the height of any dam up to that time and it was to be so thick that unless artificially cooled, the interior would stay warm for hundred of years. For the first time, internal heating of concrete dam was tackled as a major problem. At first, it was thought that the solution would be to develop a cement with low enough heat liberation so that the temperature rise would be tolerable. A low-heat cement was indeed developed and used in the dam. But even with the low heat cement, the internal temperatures reached 150 degrees F in Hoover Dam.

Therefore, in addition to the use of low heat cement, two other measures were adopted to solve the internal heating problem. One was to cast the concrete in blocks small enough so that they would not crack. The second was to embed cooling pipes in the concrete for the circulation of cold water to remove the heat from the interior. The pipe cooling was effective in reducing the temperature and opening the joints so that they

could be effectively grouted. Some of the joints opened as much as one-fourth inch due to the cooling.

The cement content in Hoover Dam was exactly four bags per cubic yard, or 376 pounds. The cement was much coarser than present-day cement and more water was used in the concrete than would be used today. Both of these conditions made it necessary to use more cement to obtain the desired strength. Remember that Hoover was constructed before the age of internal vibrators and air entrainment. With today's cements and modern methods, a dam like Hoover could be built with much less cement.

Figure 1: Stevenson Creek Dam (1926)
Middle of top row: Marchand, Lyse, DeYoe
Center Standing: Rose and Carlson
Bottom: Slater, Fendwick, Barry