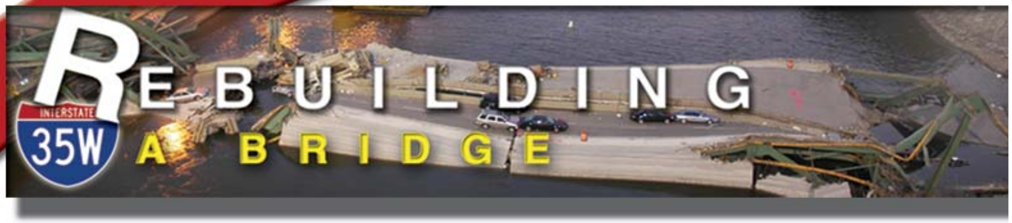

BY DR. KEVIN MACDONALD

Four deep

Cement mixes give I-35W a stable design

Minnesota and the world were shocked by the collapse of the steel truss I-35W bridge. The replacement structure requires stringent performance specs for the new concrete structure. Cemstone Products Co., an independent producer with 19 high-performance concrete bridge structures spanning the Mississippi River in the Twin Cities, worked with the design team to ensure that the bridge will perform at a level higher than specified.

While designed to have a service life of 100 Minnesota winters, the bridge also is being built on a very fast-track schedule.

Many bridge elements are large enough that concerns of mass concrete arise. To avoid expensive cooling-tube installation, concretes were designed with very low heat of hydration, extending hydration over time. Pozzolan, slag, fly ash, silica fume and other materials were used so cement is less than 50% of the cementing factor, and in many cases, considerably less. In some mixtures, cement only provides lime to start the reaction.

Performance of these concretes has been exceptional, with insitu strengths much larger than the lab strengths. The mixes also increased sustainability by reducing the amount of virgin material.

The reduced cement content allowed for reduced heat of hydration, and particularly, early heat of hydration, which is especially important when large concrete elements prevent heat from being readily dissipated. The resulting temperature differentials have been associated with stresses and cracking. Since the pozzolans do not react as rapidly as ordinary portland cement, it is easier to keep the differential temperatures lower.

Additionally, the hydration products of the pozzolan-lime reaction are formed after those of the cement reaction (although the reaction can be near-contemporaneous).

As a result, secondary deposits occur in the water-filled pores and cracks, which form during hydration. This autogenous healing densifies the material. Secondary hydration products deposited in the interfacial transition zone between the aggregates and the paste increase strength and resistance to fracture propagation.

To meet the demands of the bridge, four mixes were created:

- In the superstructure, resistance to scaling, abrasion and chloride-ion penetration is critical. The superstructure mix is a blend of cement, fly ash and silica fume, with cement in the 60% range of the total cementitious fraction;
- A second mix was optimized for the below-grade foundation elements, which consisted of drilled shafts, primarily mass concrete elements 7 to 8 ft in diameter;
- A third mix addressed the substructure, which consisted of massive elements, footings and pier stems of varying dimensions. While the heat of hydration was significant, geometries made it very difficult to insert cooling pipes. Instead of being air-entrained, the mixtures used in the below-grade structures are self-consolidating concrete. Cement represents less than 50% of the total cementitious material; and
- A fourth mixture, with cement at approximately 15% of the total cementitious material, was utilized for very low heat-of-hydration mixtures. These mixtures have an adiabatic heat rise of only about 50°F.

Performance of these concretes has been exceptional, with insitu strengths much larger than the lab strengths.

The mixes also increased sustainability by reducing the amount of virgin material, particularly portland cement and its associated carbon monoxide emissions, in the structure.

In some ways, the I-35W bridge is like any other project for Cemstone. But to anyone who was in the Twin Cities area on that fateful Wednesday in August 2007, the project is a special reminder of the importance of what bridge builders do. R&B

MacDonald is Cemstone's vice president of engineering services.