HIGH STRENGTH CONCRETE IN SOUTHERN CALIFORNIA

Production of high strength concrete (defined in this article as concrete with specified compressive strength higher than 6000 psi) requires special considerations. ACI 363R and other ACI guidelines address some recommendations on placing, compacting and curing of high strength concrete. These documents also disclose some general principles of mix design. However, design of concrete entails detailed knowledge of properties of local materials, i.e., aggregates, cement, and pozzolanic admixtures.

Strength of normal weight structural concrete is typically limited by the strength of the cement matrix. It is commonly suggested that concrete compressive strength is fundamentally inversely related to water to cementitious material ratio or, in other words, is proportional to the concentration of the solid phase in the cementitious matrix. This rule is normally valid when aggregate strength significantly exceeds compressive strength of the cementitious matrix. For high strength concrete however, it is common that the strength of aggregates to become a limiting factor that should be considered for purposes of concrete mix design along with water to cementitious material ratio.

Numerous laboratory experiments performed by Twining, Inc. show that properties of local Southern California sources of natural coarse aggregates allow the achievement of absolute compressive strength for laboratory fabricated and cured cylinders of up to 7500 - 8500 psi. This corresponds approximately to a specified design strength of 6000 - 7000 psi (UBC requires over-design of 1400 psi).

For higher strength concrete these aggregates should be crushed in order to eliminate, to the greatest extent possible, weak and imperfect particles. Crushed and properly washed aggregates exhibit better bonding to the cementitious matrix, thereby contributing to higher strength. Use of Southern California crushed aggregates with maximum size of 0.5” or 0.375” allows the achievement of 28 day absolute compressive strength of up to ~ 13,000 psi for laboratory fabricated and cured cylinders. In 56 to 90 days concrete with crushed aggregates can achieve compressive strength of ~ 14,000 psi.

Tests performed by Twining with local Type II portland cements have allowed us to conclude that water to cementitious material ratio (W/C ratio) should be limited to 0.30 in order to increase compressive strength of concrete prepared with crushed aggregates over 8000 - 8500 psi. Improvement of quality of cementitious matrix for high strength concrete requires not only W/C limitation, but also elimination of micro defects. This may be achieved by the use of highly reactive finely divided pozzolanic materials such as silica fume. Addition of pozzolanic materials also contributes to better strength development in later ages and to a higher degree of hydration of cement.

In order to keep water to cementitious material ratio as low as possible, highly effective water reducers are used. Our tests proved that it is possible to achieve a level of water reduction of 25 to 30% by the use of middle range water reducers in combination with high range water reducers at optimum proportions. This is enough to assure sufficient mobility and good workability of fresh concrete, where water to cementitious material ratio is in a range of 0.26 to 0.30.

For some of local sources of crushed aggregates Twining has established a relationship of "F'c Vs. W/C" which can be used as a basis for high strength concrete mix design. When considering the use of high strength concrete we recommend consultation with experts with extensive knowledge of local Southern California sources of aggregates, cements, pozzolanic materials, available chemical admixtures, and also expertise in the field of testing and evaluation of materials for high strength concrete.

Along with design and production, testing of field high strength concrete (as a part of quality control or inspection services) also requires special considerations. Conditions of fabricating and curing of test cylinders have significant impact on compressive strength test results. Compared to regular concrete, high strength concrete mixes are more viscous, cohesive and “sticky.” Field technicians must pay special attention to placing and compacting procedures in order to obtain dense and uniform specimens. Cylinders should be carefully inspected before testing. If necessary, their ends should be sawed or ground to meet standard tolerances. Only high strength compounds should be used for capping purpose.