The Influence of Higher Performance Materials on The Design of Concrete Structures

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Richard Unruh

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Prof. Oral Buyukozturk

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Introduction

Concrete has been used as a construction material for many centuries. The Babylonians used a form of concrete using clay as a bonding agent. British scientist John Smeaton invented modern concrete using hydraulic cement in 1756. Further advancement was made in 1824, when English inventor Joseph Aspdin created Portland cement. Joseph Monier invented reinforced concrete in 1849. In more recent times there have been advances in aggregates, admixtures and other concrete components. The introduction of high strength concrete mixtures, fiber reinforcement, and other improvements has had a dramatic effect on the design and construction of concrete structures.

Over the past several decades, advances have been made in many areas. With the development of materials such as fiberglass, carbon polymers and high strength steel, reinforcement of concrete has taken many new forms. Fiber-reinforced concrete (FRC) has many uses including strengthening existing structures and reducing the weight of a structure. Advances have also been made in the materials added to the concrete mix. Newly developed chemical admixtures as well as pozzolanic and cementitious materials have allowed builders to alter the behavior of concrete to suit almost any purpose. These materials can affect setting time, strength, workability and many other properties of the concrete. Mixes modified by these methods for special purposes are often referred to as High-Performance Concrete (HPC). A subset of HPC is High-Strength Concrete (HSC). This name refers to concrete with higher-than-normal compressive strength. These materials are often used in large buildings and bridges to reduce the size of members or to create special formations.

Fiber-Reinforced Concrete

High-Performance Concrete

HPC is differentiated from standard concrete by its special properties. HPC is often used in paving, fire protection, nuclear reactors (to reduce the amount of reinforcement needed), and other unusual structures. The special properties can include high compressive strength (for HSC), extended lifespan (75-100 years), improved workability, accelerated or retarded set, high corrosion resistance, and many others. These properties are the product of additives introduced into the concrete mix. These additives can be chemical admixtures, pozzolans or cementitious materials.

Chemical Admixtures

Chemical admixtures have many uses, depending on the type of admixture. Some of the more common uses include:

- Improving workability
- Reducing water content

- A combination of workability/water content improvements
- Accelerating or reducing setting time
- Reducing aggregate separation and/or bleeding
- Improving pumpability
- Accelerating strength development
- Increasing strength
- Increasing durability and reducing permeability
- Reducing overall cost of materials
- Compensating for poor aggregate properties

To produce these benefits, a variety of admixtures have been developed. These substances include:

- Water-reducers (plasticizers & super-plasticizers)
- Set accelerators (such as calcium chloride)
- Air-entraining agents
- Corrosion inhibitors
- Expansion-inducing agents
- Set retarders

The properties of each of these products will be detailed below.

Water Reducers

Water Reducers, also called Plasticizers, are used to lower the water content of a concrete mixture. Some water reducers can lower the required water needed in a mix by 10%. The agents can also increase the strength of the concrete, since they change the water-cement ratio. Descriptions and uses of various water reducing agents are given in ASTM C494. Special High Range Water Reducers (HRWR), also called Superplasticizers, can reduce the needed water for a given slump by 12 to 30%, giving a larger increase in strength. Adding these agents without reducing added water can improve the "flowability" of the mix. A normal dose of HRWR will increase slump from 3 to 4 inches up to 8 inches. The slump returns to normal after 30 to 60 minutes. HRWR's are governed by ASTM C494 and C1017.

Set Accelerators

These admixtures are used to reduce the time needed for the concrete to 'set' or cure. Accelerators are generally recommended in cold weather. They do not have any anti-freeze effect. Instead, they accelerate strength gain, allowing the concrete to better resist freeze damage. Calcium chloride is the most commonly used accelerator. Use is recommended at not more than a 2% ratio by weight with the cement. Side effects of using calcium chloride can affect rebar corrosion, drying shrinkage, creep, heat evolution and resistance to sulphate attack. These effects can generally be accommodated through careful planning. Use of calcium chloride can offset strength reduction at temperatures as low as 40 to 50 degrees Fahrenheit. Non-chloride accelerators have some additional benefits. First, they can be used at a wider variety of temperatures (as low as 20 degrees Fahrenheit). The second benefit is a reduction in corrosion potential. Finally, non-chloride accelerators provide even better early strength gain. Accelerators are covered by ASTM C494 types C and E.

Air Entrainers

Air entrainers are formulated from organic materials such as wood resins, sulphonated hydrocarbons and synthetic detergents. The purpose of air entrainers is to produce microscopic air bubbles in the concrete to produce several benefits:

- Improve freeze-thaw resistance
- Reduce bleeding
- Improve workability

Specifications require air entrainment of 5 – 8% for concre4te poured outside. Entrainment is not needed inside, since there is no risk o f freeze-thaw damage. Air entrainment is covered in ASTM C260 and ACI 116R-90.

Corrosion Inhibitors

Expansion-Inducing Agents

Set Retarders

Set retarders increase the curing time for concrete. They are derived from two main sources: salts of lignosulphonic and hydroxy carboxylic acids. Some are derived from detergents, sugars and silicones. These admixtures also provide some benefit as water-reducers and workability agents (water reducers are derived from the same materials, but have the retarding actions reduced or eliminated). Lignosulphonate retarders can also reduce bleeding and provide some air entrainment, while hydroxy carboxylic agents have the opposite effect. Retarders can delay the initial set by 1 to 3.3 times, and the final set by no more than 3.3 times. These admixtures are governed by AST C494 types B and D.