Application of FA and BFS in practice

Prof. Tetsuya Ishida, The University of Tokyo

Industry as a whole is required to make efforts to reduce the carbon dioxide (CO_2) emissions that cause global warming. The construction sector generates a large quantity of CO_2, with the production of Portland cement (a component of concrete) accounting for around 4% of Japan's total carbon footprint. Sixty percent of this CO_2 is released through the thermal decomposition of limestone during cement production. To reduce limestone use, attention has turned to replacing some of this essential raw material with other ingredients to form mixed cements. The Japanese Cabinet endorsed expanded use of mixed cements incorporating blast furnace slag powders, fly ash, and other materials in its "Global Warming Control Plan" of May 2016.

In response to this movement, the JSCE published "Guidelines for Design and Construction for Concrete Using Blast Furnace Slag Powders" (Concrete Library 151) in 2018. These guidelines incorporate the latest understanding of JIS-defined blast furnace cement types A, B, and C (in which cement is substituted by blast furnace slag powders at ratios between 30% and 70%). Moreover, "Guidelines for Design and Construction of Concrete Structures with High Admixture Ratios (Proposal)" was also released in the same year. These guidelines focus on cements with substitution ratios of admixtures such as blast furnace slag powders, fly ash, and silica fume that exceed the JIS standard (that is, with an admixture content of 70% or more). These new guidelines aim to further reduce CO_2 emissions by encouraging wider use of concretes that include industrial byproducts and waste as admixtures, which have seen a rising market share since enactment of the "Green Purchase Act" in 2000.

Concrete made with cement containing such admixtures has different performance and quality characteristics than that using ordinary Portland cement. As a result, careful handling is required. For instance, concrete workability changes with a rise in viscosity. When fly ash is used, an air-entraining (AE) water-reducing agent is used to adjust viscosity and this results in characteristics that differ remarkably from Portland cement concrete (in terms of slump loss and air entrainability). Moreover, because chemical reactions take place more slowly, the concrete develops strength in a different way. On the other hand, admixtures are highly effective in improving durability. For example, they can reduce the risk of cracking caused by hydration heat, curb the alkali-silica reaction, and improve resistance to the infiltration of chloride ions. Given this complexity, it is not advisable to use these admixtures in a passive way solely for such environmental reasons such as CO_2 reduction; rather, their great potential to add value through enhanced durability should be leveraged.

Specifications-based approaches to material selection and blending design are not an effective way to fully utilize the advantages of concrete with admixtures. Rather, it is important to evaluate the physical underpinnings of changes in mechanical characteristics and durability over time through the use of physics models and design equations based on a proper understanding of the concrete. The differences in physical properties from those of ordinary Portland cement result from the different phase constitution and characteristics of hydrates such as calcium silicate hydrate (C-S-H). Further, the vitrification efficiency, composition and unburned coal fraction of fly ash vary greatly depending on the original raw coal used, the combustion method, and the dust collection method, which in turn greatly affect the physical properties of the final concrete. Taking into account this variability, there is a need to establish a general evaluation method that reflects the mechanisms operating at the microscopic level and build physio-chemical models that are applicable to a wide range of raw materials.

Attention must also be paid to a recent world trend that is spurring study of the heavier use of admixtures (also known as supplementary cementitious materials): concern about the possible future shortage and depletion of raw limestone. Work is ongoing to develop cements that contain a minimal quantity of raw limestone and geopolymer concrete, in which alkali stimulation is used to harden blast furnace slag powders and fly ash. Thus, the next-generation construction materials needed to support a sustainable society and curb global warming are under development. The potential of admixtures will be further exploited in the future.