Activity Summary of JSCE Subcommittee 353

Subcommittee on Evaluation Techniques for Physical Properties of Concrete Using Admixtures and Performance-based Material Design


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1. Purpose of Establishment

A wide variety of admixtures has been increasingly used in concrete in response to the demand for high performance and improved functionality. The quality of each admixture has conventionally been specified in JIS and other standards. On the other hand, the physical properties of concrete using blast furnace slag powder have been largely clarified by the 'Subcommittee on Design, Material Characterization, and Performance Evaluation of Concrete with Admixtures' (subcommittee 333).

In order to solve the remaining problems of Subcommittee 333, the subcommittee 353 systematized a characterization method incorporating the latest analytical methods and developed a method for evaluating the physical properties of concrete containing admixtures materials such as fly ash.

Furthermore, the subcommittee 353 has studied the structure of a design system that appropriately sets a material design based on these property evaluations in the structural plans.

2. Subcommittee Working Group (WG) Composition and Roles

Under this subcommittee, which is a research committee for the introduction of material design into the design of concrete structures, the following working groups (WGs) were established and are now undertaking investigations and studies.

(1) WG1 (Working Group for Systematization of Performance-Defined Design)

The purpose of this working group is to compile knowledge that will help ensure that structural plans take appropriate account of performance-based material design according to the performance required of a structure according to environmental conditions at its location, including salt resistance, neutralization resistance, ASR resistance, and low permeability.

(2) WG2 (Analytical and Physical Properties Evaluation Working Group)

The first objective of this working group is to organize and systematize the applicability and evaluation of individual analytical methods for assessing the material performance of cement concrete and the

property changes it undergoes.

The second objective is to summarize the characteristics of existing constitutive models for evaluating the long-term properties of concrete in the environment in which it is located.

The third objective is to identify problems with and required improvements to existing property evaluation models that are necessary for the systemization of performance-driven material design.

(3) WG3 (Fact-finding Working Group)

The first objective of this working group is to identify the technical basis for provisions relating to the evaluation of material properties and degradation mechanisms in the current design standards.

The second objective is to investigate the diversity of available admixture materials and their characteristics and performance in the context of changing social conditions.

The third objective is to investigate changes in cement performance with changes in the manufacturing method.

3. Subcommittee Proposals and Considerations

(1) Introduction of material design into the design of concrete structures

The committee proposed that, in order to develop a structural design system in which material design based on evaluation of physical properties is appropriately reflected in structural plans, it is important to clearly divide the performance requirements of a concrete structure into structural performance and physical property performance, as shown in Figure 1.

Furthermore, as shown in Figure 2, the current design system for concrete structures includes only structural performance requirements. Mutual collaboration between structural and material designers is essential to satisfy the proposed performance requirements for concrete structures. Coordination among the two is key to good or bad design; the collaboration determines the success or failure of a design.

There are concerns that the material designer may fall into a subordinate relationship to the structural designer. Therefore, we propose a clear divide in responsibilities, with the structural designer responsible for structural performance and the material designer responsible for physical properties.

Here, material performance relates to the degradation of a structure, meaning the performance-related effects of changes in the materials (substances) that make up the structure. This is generally referred to as durability and does not represent a new concept.

However, the current design criteria for concrete structures do not specify material performance, indicating that it is necessary and important to clarify this aspect of performance when long-term performance evaluation and design for a service life of more than 100 years is required.

(2) Necessity of Material Design

The cements used for concrete structures in public civil engineering projects in Japan today are mainly mixed cements. They contain blast furnace cement, fly ash cement, and other industrial wastes as a result of measures to reduce emissions of carbon dioxide, a global warming gas.

However, it is questionable whether sufficient performance evaluation of these mixed cements has been

completed for cases where admixtures such as high-performance water-reducing agents are added to improve workability (flowability) and increase strength.

In the current Japanese standards for concrete, individual materials are standardized in JIS and other standards. However, these standards only specify performance for use of a particular material alone, and do not apply when it is mixed in various ways.

Furthermore, there are no durability requirements in the national technical standards and there are no provisions for durability in JIS.

(3) Difference between Material Design and Mix Design

As an example of the current state of material design in the design of concrete structures, consider the standard design and construction process for prestressed concrete bridges. In the current design standards, material selection for material design is based only on material properties given by JIS and other standards. Material selection here refers to the selection of a material for a ready-mixed concrete with a strength specified by JIS to satisfy the structural performance requirements of the structure. That is, it remains a conventional mix design.

The process of material design proposed by this committee does not mean mix design, but rather the specification and selection of materials with qualities that will allow the structure to meet the required performance considering the environmental conditions of the site where the structure will be constructed. This includes qualities that give the concrete properties such as resistance to chloride ions, which cause steel corrosion, and resistance to the diffusion of atmospheric carbon dioxide, which causes neutralization. In other words, the proposed material design concept is significantly different from conventional mix design, in which strength and workability are considered on the basis of combinations of materials.

(4) Need for Material Evaluation Technology in Material Design

In the design of concrete structures, it is important to evaluate the performance of substances in the hardened cement that form the concrete matrix in order to ensure load-bearing capacity and long-term service life in consideration of age-related deterioration. Therefore, it is necessary to develop a method (micro-level material design method) for estimating temporal changes in the physical and chemical properties of calcium silicate hydrate (C-S-H) and calcium aluminosilicate hydrate (C-(A)-S-H), which form the hardened cement matrix, under varying environmental conditions. The development of such a micro-level material design method will require various analytical techniques for the hardened cement matrix microstructure and material evaluations based on analytical results. Furthermore, the evaluation of the hardened cement microstructure using various analytical techniques provides results for the micro level. On the other hand, the performance of concrete structures is evaluated at the macro level, and there is a large difference in scale from the micro to the macro level.

It has been pointed out that the development of a coupled model that relates micro-level material evaluations to macro-level performance evaluations of concrete structures is an important issue for the future development of a micro-level material design method.

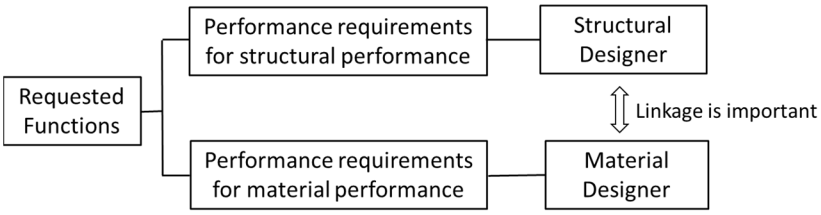

Figure 1. Proposed design system

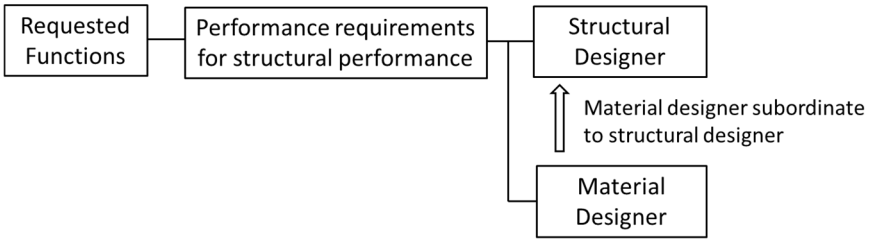

Figure 2. Current design system