Standard Specifications for Concrete Structures

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Limit State Design Method and Safety Factors

In 1968 the JSCE Concrete Committee established the "Ultimate Strength Design Sub-committee" with mainly younger members, and it commenced its work of study and research. Some of the results of that work were published in 1972 as "Ultimate Strength Theory Reference" for reinforced concrete, and in 1975 as "Recent Trends Design Methods" for reinforced concrete. Thereafter the study and research work continued with the objective narrowed down to the amendment of the Standard Specifications for Concrete Structures, leading to the publication in 1977 of "Design Recommendations Second Draft" for concrete structures, and the publication in 1981 of "Draft Proposal on the Limit State Design Method" for concrete structures.

The "Ultimate Strength Design Sub-committee" was reorganized into the "Limit State Design Method Sub-committee", where further investigation proceeded, mainly in the Steering Committee, leading to the publication in 1983 of "Limit State Design Recommendations (Draft)" for concrete structures. In 1986 the "Design Volume" of the Standard Specifications for Concrete Structures was adopted having virtually the same content, so 18 years after the start of studies and research the method finally saw the light of day.

One of the main debates when producing the "Draft Proposal on the Limit State Design Method" was the number of safety factors. In design methods based on the allowable stress or the ultimate strength the number of safety factors used was substantially 1. In the "CEB-FIP Recommendations" which adopted the limit state design method it was proposed that 2 safety factors be used. We divided the safety factor used in the process of obtaining the design value of a member load resistance into a material factor and a member factor, and divided the safety factor used in the process of obtaining the design value of member cross-sectional force from external forces into a load factor and a structural analysis factor, and added a structure factor used at the stage of comparing the cross-sectional force and the cross-sectional load resistance, to give a total of 5 safety factors. This was to allow for progress made in concrete technology to be reflected in each of the safety factors. In the subsequent editions of the Standard Specifications for Concrete Structures this concept has been retained.

The main purpose of dividing the safety factor used in calculating the member load resistance into the material factor and a member factor was to be able to independently incorporate progress in materials and construction and progress in equations for calculating load resistance. Basically the material factor takes into consideration the effect of construction, and the member factor takes into consideration the uncertainties in the equations for calculating load resistance.

Reinforcement is virtually unaffected by construction, but in contrast the quality of concrete is greatly affected by quality of the in-situ construction. However reinforcement is affected by the construction of joints, so it is desirable that the value of the material factor be defined in accordance with the reliability of the construction. In concrete also the value can be reduced for concrete with little segregation or for high reliability construction.

The method used to date is to use empirical equations approximating the lower bound values for shear resistance, and to represent the average values in equations for calculating the bending resistance, etc., based on theoretical considerations. The accuracy of the empirical equations is expressed by the value of the member factor, consistent with the latter concept. Note that it is convenient to deal with the importance of a member such as a slab, beam, or column, with this factor. Also, the member factor for the shear resistance is larger relative to that for the bending resistance, which enables the seismic performance to be improved.

Durability Design

The "Durability Design Sub-committee" was established in April 1988, and in August of the following year it published "Recommendations for Durability Design (Draft Proposal)" for concrete structures. This contained comprehensive and quantitative durability design methods, specific environmental indices, and durability indices. A revised version of this was published in 1995.

In the 1999 edition of Standard Specifications for Concrete Structures, "Construction" – Verification of Durability -, various rules were provided for improving the durability, with an independent chapter on verification of cracking at the construction stage. Also, the concrete performance was categorized into the required performance at the construction stage and the required performance at the maintenance stage, clearly distinguishing between quality management and inspection.

The standard specifications assume the technical level at the time of publication, so that structures of a certain level of higher can be produced, but there is always the possibility that they can hinder the progress of technology. Therefore, it is desirable that amendments be made when necessary, and that a system be adopted to enable new technology to be easily incorporated. These Standard Specifications were produced with an awareness of this. However, they were certainly inferior to the 1996 version of "Construction" in terms of ease of use, but as the contents were substantially the same, either one could be used.

For each type of structure, the recommended materials and construction methods are naturally defined by the technical level at that time. It is the role of outstanding engineers to propose these materials and methods based on the Standard Specifications. I think one example of this is "Recommendations for Mix Design of Fresh Concrete and Construction Placement related Performance Evaluation (Draft)" published in 2007. It is desirable that more of these type of recommendations are produced.