Subcommittee 351

Design and performance evaluation by coupled method for concrete structures

Purposes of subcommittee

Various trials and researches on design and performance verification method of concrete structures has been conducted for tens of years in Concrete Committee in JSCE, especially on seismic performance verification, framework of long-term performance evaluation, system of design that utilizes the advanced techniques, etc. However, the sufficient numbers of trials have not necessarily been conducted that the developed individual engineering/scientific techniques are systematically organized on the design and performance verification system of concrete structures. For example, deformational behavior of concrete members due to creep and shrinkage, seismic behavior of structures considering the influence of soil foundations, fatigue behavior of bridges due to high-cycle traffic loads, and deterioration of concrete materials due to environmental actions and its influence on structural behaviors, are drastically developed for these ten years, but the interrelation between those behaviors has not yet been fully considered in the performance evaluation system of newly-built and existing concrete structures throughout their life in time domain. This subcommittee 351 investigates 1) short- and long-term coupling performance verification techniques of structural system including soil foundation, 2) long-term coupling performance evaluation techniques of concrete structures in time domain, and 3) design system of structures in which various advanced coupled methods are fully utilized. These investigations, in the future, will be combined as one system that realizes the performance evaluation of concrete structures “as they are”.

Organization and roles

This subcommittee consists of 40 members from universities, research institutes, construction companies, design consultants, etc., and they are allocated into the four working groups, WG1: soil interaction problems, WG2: performance evaluation, WG3: time domain, and WG4: engineering application, those are related to the purposes of the subcommittee as shown in **Figure-1**.

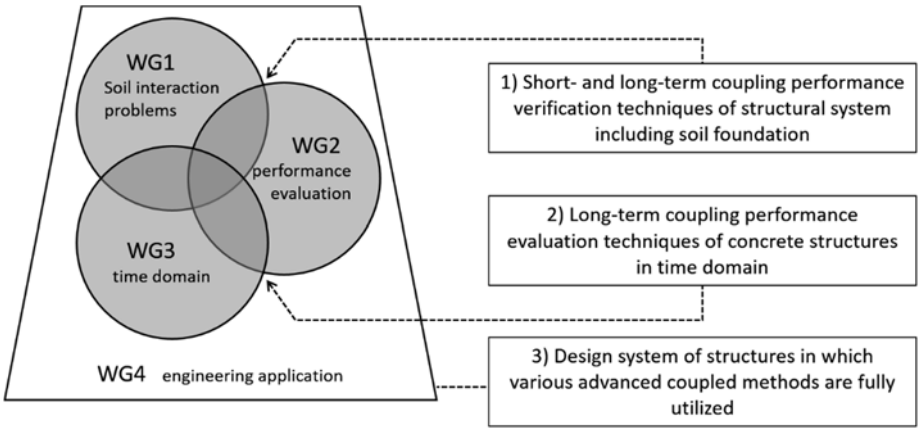

Figure-1: Purposes of subcommittee and four working groups

WG1 especially investigates the mechanical interaction between underground RC structures and surrounding soils under normal and seismic conditions, and explores the advanced and rational evaluation method, coupling method

of thermal analysis for concrete placement and mechanical structural analysis under service loads, and the interaction between internal drying shrinkage, resultant deformation and soil pressures, etc. WG2 especially investigates the performance evaluation method for newly-built concrete structures, such as long-term deformation of concrete structures due to creep and shrinkage, performance evaluation system that unifies the behaviors both under normal and seismic conditions, rational evaluation method of statically-indeterminate structures, and rational design of structural member connections, etc. WG3 especially investigates the performance evaluation method for existing concrete structures, such as the rearrangement of performance evaluation methods of deteriorated structures, interaction between structural behaviors and material deteriorations due to various environmental actions, methods to relate information obtained from inspections and monitoring to structural performance evaluation, and modelling of various external actions to structures throughout their lifetime, etc. WG4 mainly investigates, based on the perspectives of investigations by the above three working groups, the total system of design, construction and maintenance of structures for near future, and plays a role to extract the engineering technical problems and to feedback them to the other three working groups.

Basic concepts of investigations

The primary basic concept of investigations in this subcommittee is to develop the evaluation method of structures "as they are". In the current structural design system bases on the combination of partial design methods for structural members which a target structure is divided into (see **Figure-2**). This kind of separated method bases on, to some extent, the very limited design conditions and cannot be directly applied to the evaluation of existing structures. Thus, the method to evaluate directly structural performance is needed that can be applied both for new and existing structures.

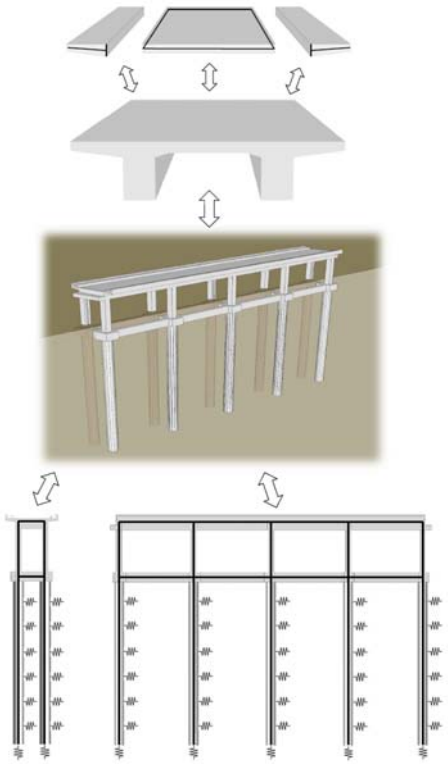

Figure-2: Basic concept – performance evaluation of structures "as they are"

The other basic concept of investigations in this subcommittee is to couple the various existing techniques simultaneously in the performance evaluation. Here, the word "coupling" is used, in this subcommittee, as a way of considerations and phenomena in a series and a parallel manners. For example of concrete structures, the combinations of "coupling" can be listed as follows:

a) Physical and chemical phenomena (sometimes, geological and biological ones are also considered)
b) Material and structural behaviors
c) Members and structural system behaviors
d) Several external actions (synergistic effects in a better or worse sense)
e) Actions and responses (interaction)
f) Individual evaluation methods
g) Spatial and timewise coupling (four-dimensional world)

Figure-3 shows the schematic view of a lifetime of structures given by the past subcommittee 329. Structures are subjected to various external mechanical and environmental actions throughout their service life and exhibit various levels of responses. Sometimes, repairing and strengthening are provided when damaged. Such repaired and strengthened structures, of course, respond in a bit different manner for same external actions. The ultimate objective of this subcommittee is to evaluate precisely, as much as possible, the performance of target structure under various external mechanical and environmental actions throughout its service life.

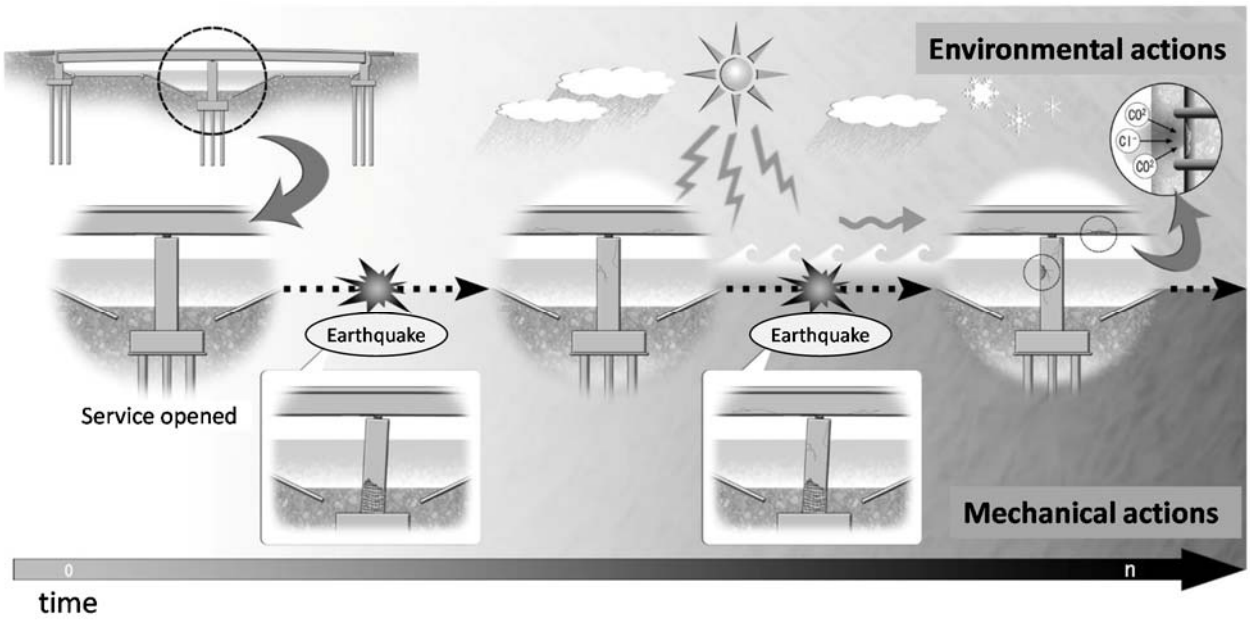

Figure-3: Schematic view of a lifetime of structure

Current results and future perspectives

This subcommittee completed its first batch activity (for two years since 2015) and had published the report of research results in the end of June in 2017. One typical example of investigation is to analyze the railway RC frame viaduct under moving train loads using nonlinear three-dimensional finite element method as shown in **Figure-4**. The influence of material deterioration on the deformation of the viaduct by using this model. This kind of method

has a wide applicability to various types of external actions, and can evaluate the structural performance with consideration of several actions simultaneously. Regardless of new or existing structures, the overall framework of performance evaluation system of concrete structures is gradually in sight. The problems to realize the system are also becoming clear. Based on the result obtained in the first batch, the second batch of activity will be starting in the end of 2017.

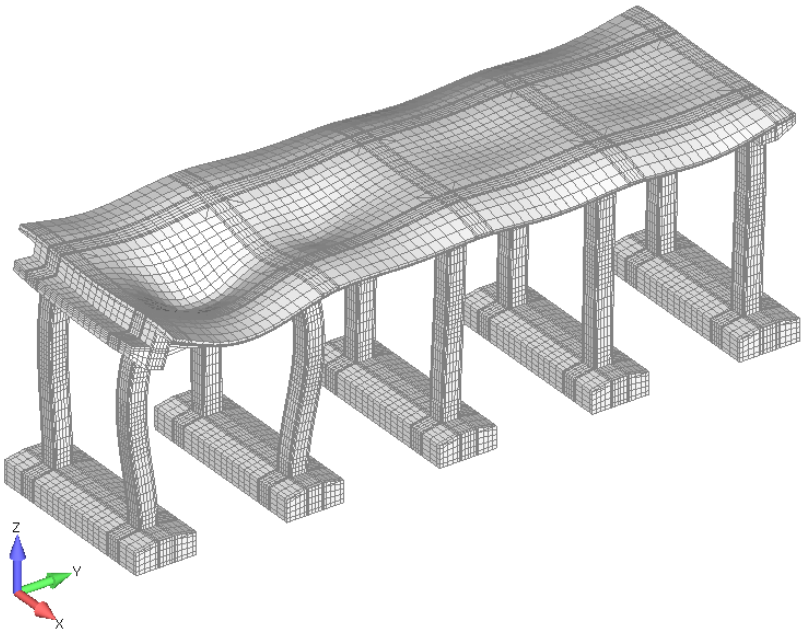

Figure-4: Example of deformation of railway RC frame viaduct under moving train load by 3-D FEM