Title: “Quality and durability attainment system for concrete structures in Tohoku region”  
(Activity of committee 229)

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1. Introduction

Enormous efforts have been made by past engineers for quality & durability attainment of concrete structures. The author and his colleagues have continued systematic efforts for quality & durability attainment whose origin was in the crack control system developed by Yamaguchi prefecture in Japan. In Yamaguchi system, a revolutionary A4 sheet called “Construction Conditions Tracking Check Sheet” was developed (Figure 1). The original check sheet developed in Yamaguchi prefecture clearly lists 27 essential measures for appropriate concreting work to achieve high quality of concrete. Furthermore, a crack control design system not requiring expensive numerical simulation of thermal stress was established based on a database of construction records of existing structures. In actual use, this system has been found to dramatically reduce harmful cracking and improve concrete quality.

After the Great East Japan Earthquake in March 2011, construction of a highway network totaling 584 km called the “Revival Road” in Tohoku region was launched in the disaster area. This highway network includes some 200 new bridges and some 100 new tunnels. The check sheet mentioned above is being used to prevent initial defects in the Revival Road, which is being built in a very short time with limited human and material resources. To achieve 100-year durability under very severe environmental conditions including the spraying of huge amount of de-icing agent, advanced durability design exceeding the design codes of Japan is being adopted.

In this newsletter, essential points of quality & durability attainment system in Tohoku region will be explained.
2. Quality attainment system in Tohoku regional development bureau

In August 2012, due to the proposal by the author and some of his colleagues, site investigation of quality of concrete structures in Tohoku region was conducted. In 2013, efforts for quality attainment of concrete structures have been started in Tohoku regional development bureau. In Tohoku bureau, a new quality attainment system was established where the check sheet developed by Yamaguchi system was combined with “Visual Evaluation Method” developed by the author and his colleagues to make a PDCA system to achieve uniform, well compacted, and united concrete structures without cold joints (Figure 2). Furthermore, long-term curing was recommended to make concrete denser for achieving durability in cold severe environment in Tohoku region. In the newly established guidelines by Tohoku bureau for general concrete structures and for NATM tunnel concrete lining, this PDCA system is specified and the evaluation method for concrete quality utilizing non-destructive tests such as surface water absorption test and air permeability test are also specified.

This PDCA system using the check sheet and the visual evaluation method has been applied in the test construction of actual structures in all the regional bureaus in 2017. The results of those test constructions should be examined and fed back to establishing future quality attainment system in Japan.

Check sheet includes 27 items as follows:

- **Preparation (8 items)**
  - e.g., The height of one layer is less than 50cm.

- **Transportation (1 item)**

- **Placement (9 items)**
  - e.g., Internal vibrators are inserted about 10cm into the lower layer of concrete.

- **Compaction (5 items)**
  - e.g., Internal vibrators are inserted about 10cm into the lower layer of concrete.

- **Curing (4 items)**
  - All are basic matters in concreting.

So, “Revolutionary” means to do our work properly as a construction management.

Figure 1 “Construction Conditions Tracking Check Sheet” developed by Yamaguchi prefecture
3. Durability design in cold aggressive environment

In order to really achieve durability of concrete structures in very cold aggressive environment as in Tohoku region, only good concreting work is not appropriate. Appropriate durability design is necessary, and a multiple protection durability design philosophy proposed by Prof. Iwaki, et al. has been installed in Tohoku bureau. Figure 3 shows the multiple protection durability design system for upper structure of bridges in Tohoku. In order to avoid progressive deterioration caused by 3 or 4 combining mechanisms, 5 countermeasures are combined. In this multiple protection system, fly ash or ground granulated blast-furnace slag should be utilized to control ASR and the ingress of Cl- under the effects of de-icing agent, and expansive additive also should be appropriately utilized to control cracking. Sufficient entrained air should be specified in the design of mix proportion and the air content of concrete should be well controlled in practice.
Some examples of severe deterioration of bridge structures are exhibited in Figure 3. Severely deteriorated RC slabs have been replaced in real structures. Figure 4 shows an example of cost for replacement of RC slab in an actual structure. Total cost necessary for the demolition of the structure and replacement by PC slab was more than 4 times expensive than the initial cost. The cost for durable RC slab utilizing fly ash designed based on the multiple protection system is also exhibited in Figure 4. The cost for the durable RC slab is 1.26 times of that for the conventional RC slab. The most of the increase of the cost is due to epoxy-coated re-bars. We should consider the effect of durability design from the viewpoint of life cycle cost.
Figure 4  Cost of durable RC slab

4. Summary

The quality and durability attainment system developed in Tohoku bureau is one of the approaches to achieve durability of concrete structures in aggressive environment. In Japan, we will face more difficult situations to achieve durability of concrete structures, due to drastic lack of human labor, lack of good aggregate, etc. The effects of de-icing agent on durability of concrete structures have not been directly considered in durability design in Japan, therefore, appropriate durability design considering the environmental actions should be implemented into practice. The conditions of the structures designed and constructed in Tohoku bureau system should be monitored, and analyzed results should be fed back to improve the system in the future.