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

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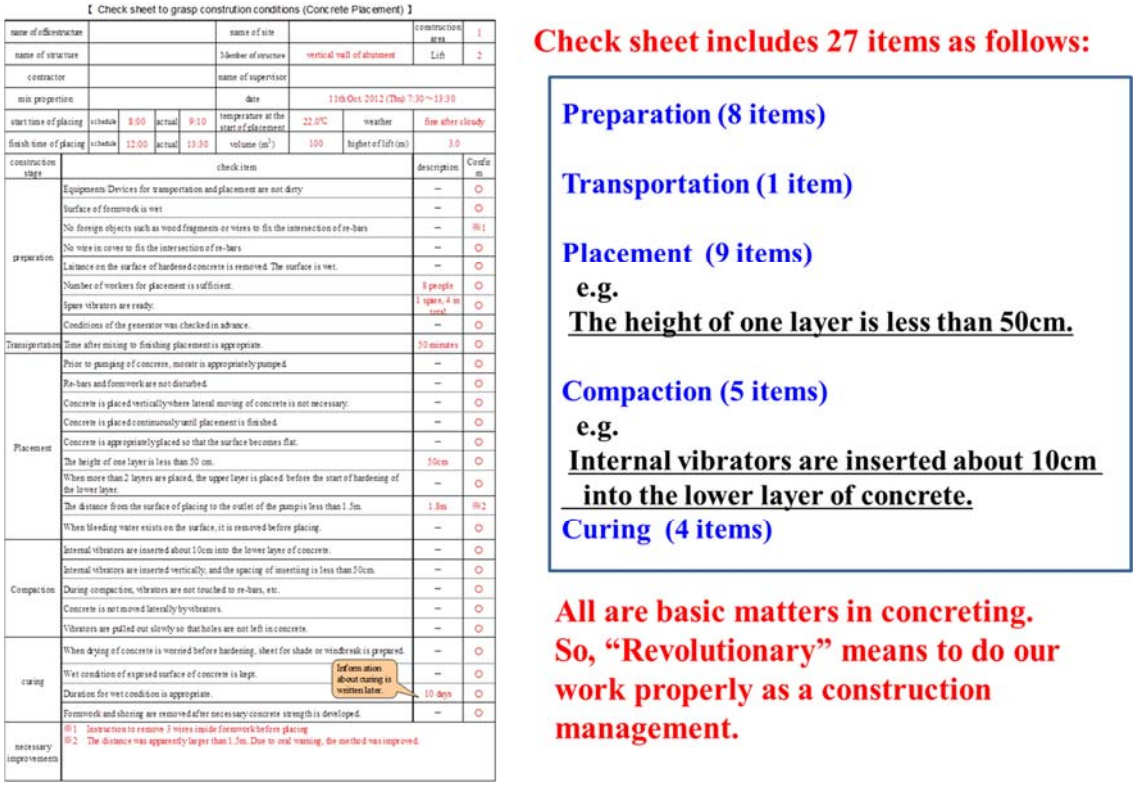
1. Introduction

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 covercrete 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.



【 Check sheet to grasp construtions conditions (Concrete Placement) 】

name of office/structure					name of site			construction area	1
name of structure					3dember of structure	vertical wall of abutment		Lift	2
contractor					name of supervisor				
mix proportion					date	11th Oct. 2012 (Thu) 7:30～13:30			
start time of placing	schedule	8:00	actual	9:10	temperature at the start of placement	22.0℃	weather	fine after cloudy	
finish time of placing	schedule	12:00	actual	13:30	volume (m³)	100	highet of lift (m)	3.0	

construction stage	check item	description	Confirm
preparation	Equipments/Devices for transportation and placement are not dirty	–	○
	Surface of formwork is wet	–	○
	No foreign objects such as wood fragments or wires to fix the intersection of re-bars	–	※1
	No wire in cover to fix the intersection of re-bars	–	○
	Laitance on the surface of hardened concrete is removed. The surface is wet.	–	○
	Number of workers for placement is sufficient.	8 people	○
	Spare vibrators are ready.	2 spare, 4 in total	○
	Conditions of the generator was checked in advance.	–	○
Transportation	Time after mixing to finishing placement is appropriate.	50 minutes	○
Placement	Prior to pumping of concrete, mortar is appropriately pumped.	–	○
	Re-bars and formwork are not disturbed.	–	○
	Concrete is placed vertically where lateral moving of concrete is not necessary.	–	○
	Concrete is placed continuously until placement is finished.	–	○
	Concrete is appropriately placed so that the surface becomes flat.	–	○
	The height of one layer is less than 50 cm.	50cm	○
	When more than 2 layers are placed, the upper layer is placed before the start of hardening of the lower layer.	–	○
	The distance from the surface of placing to the outlet of the pumpis less than 1.5m.	1.0m	※2
	When bleeding water exists on the surface, it is removed before placing.	–	○
Compaction	Internal vibrators are inserted about 10cm into the lower layer of concrete.	–	○
	Internal vibrators are inserted vertically, and the spacing of inserting is less than 50cm.	–	○
	During compaction, vibrators are not touched to re-bars, etc.	–	○
	Concrete is not moved laterally by vibrators.	–	○
	Vibrators are pulled out slowly so that holes are not left in concrete.	–	○
curing	When drying of concrete is worried before hardening, sheet for shade or windbreak is prepared.	–	○
	Wet condition of exposed surface of concrete is kept.	Information about curing is written later.	○
	Duration for wet condition is appropriate.	10 days	○
	Formwork and shoring are removed after necessary concrete strength is developed.	–	○
necessary improvements	※1 Instruction to remove 3 wires inside formwork before placing ※2 The distance was apparently larger than 1.5m. Due to oral warning, the method was improved.		

Check sheet includes 27 items as follows:

Preparation (8 items)

Transportation (1 item)

Placement (9 items)

e.g.

The height of one layer is less than 50cm.

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

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 covercrete 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 covercrete 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.

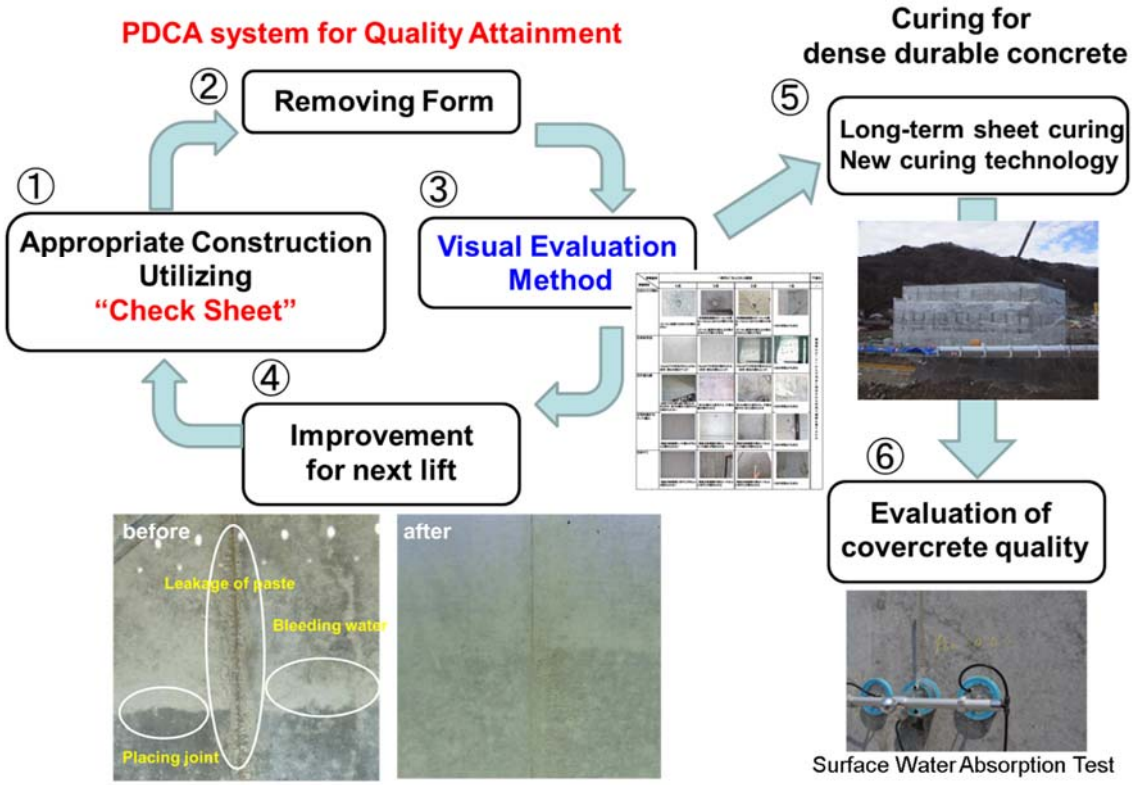


Figure 2　Quality attainment system newly developed in Tohoku bureau

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.

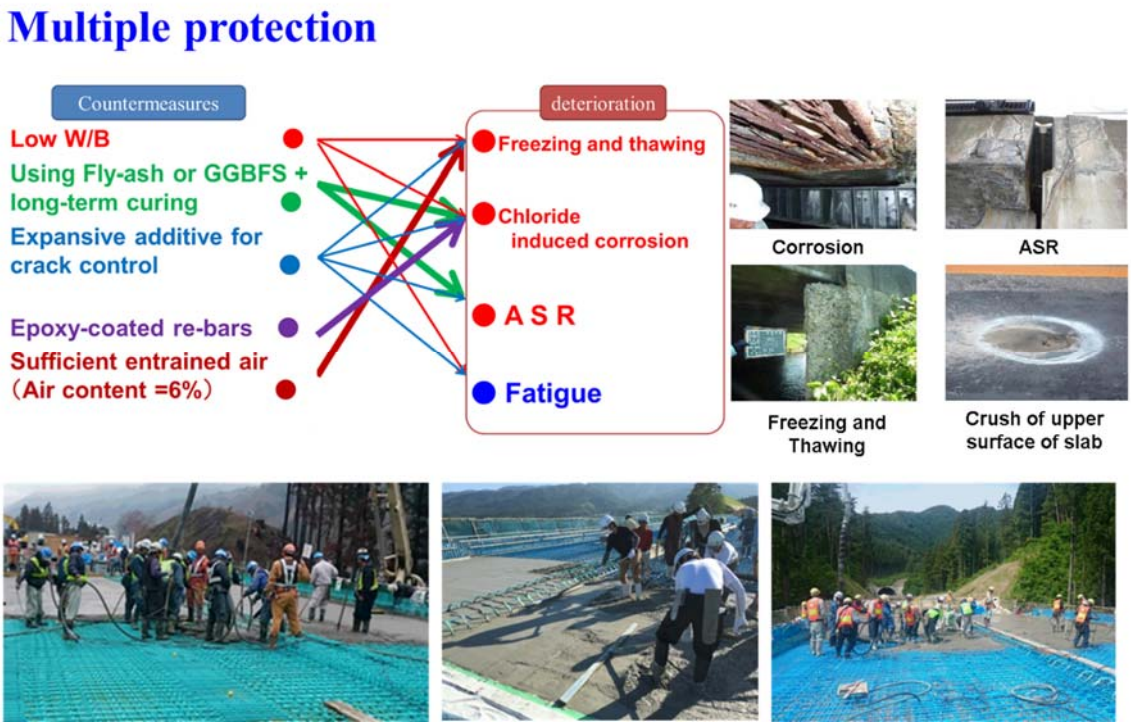


Figure 3 Multiple protection durability design system for bridges in Tohoku region

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.

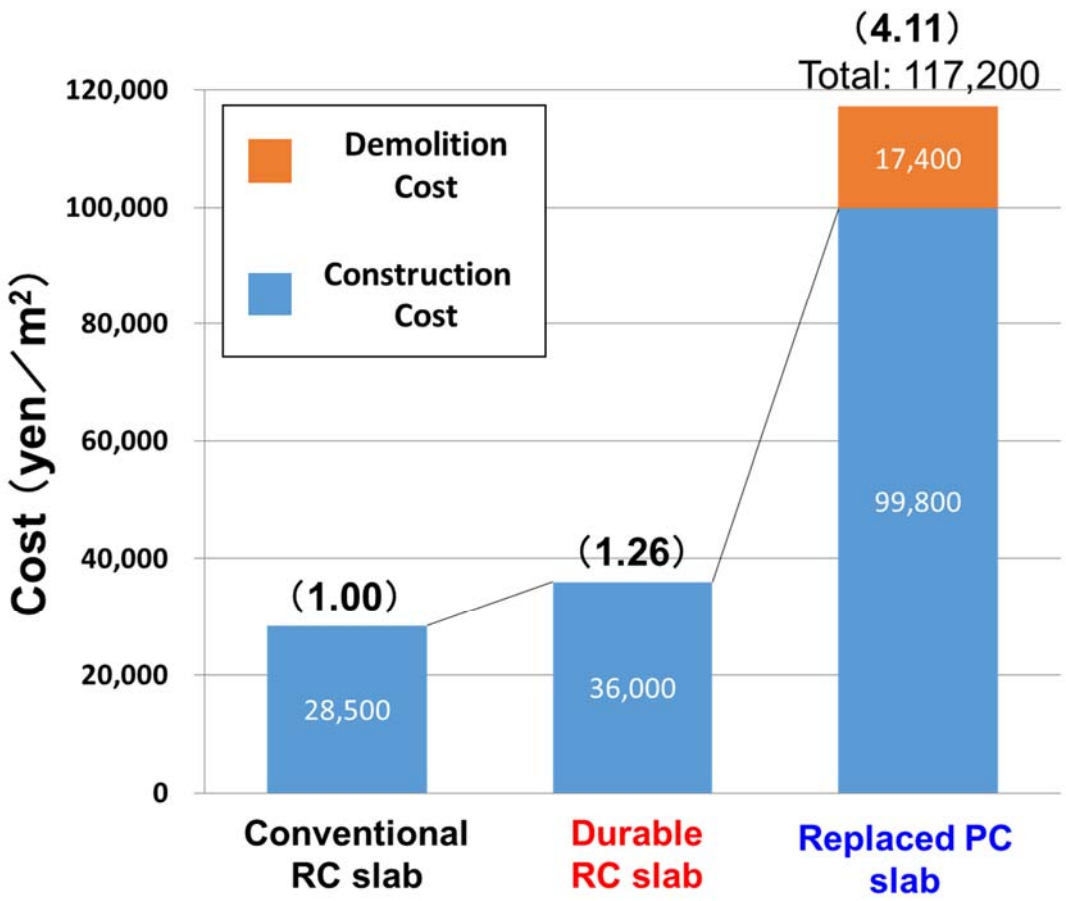


Figure 4　Cost of durable RC slab

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.