ABSTRACT

Title: Study on large precast box culverts as an alternative construction method for small bridges in cold regions

Doctor Course in Civil Engineering — Doctor of Engineering

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[Abstract]

Infrastructure maintenance in Japan has been dominated by the construction of many structures during the period of rapid economic growth from the 1950s to the 1970s. Generally speaking, the lifespan of bridge is about 50 years, and the number of structures that are now 50 years old after construction continues to increase. Therefore, road infrastructures including bridges and tunnels have recently been desired to be repaired or reinforced to extend their service lives, and new structures to be constructed in the future must be developed sustainably to reduce LCC and contribute to the SDGs.

On the other hands, due to the declining population, Japan faces not only the problem of a decrease in engineers and technicians, but also the task of reducing construction costs. In particular, the infrastructure maintenance in local governments is very difficult, especially when accompanied by the extremely harsh conditions of snowy and cold regions such as Aomori Prefecture.

A survey of bridges in Aomori Prefecture and of engineers for infrastructure maintenance was conducted in this study. From the result of survey, issues and/or requests were extracted as follow: 1) the use of a box-culvert as an alternative structure of small scale bridge is expected, because of the verification and/or maintenance of bridges are complex, regardless of its scale. 2) the application of a pre-cast product is expected, because to deal with a decrease of maintenance engineers. 3) more high level durability that is deal with severe and harsh environment condition is required.

In this study. Some issues that is concerned for the application of pre-cast box-culvert as an alternative method for small-scale bridge were examined from the viewpoint of materials, quality-controls and constructions.

In Chapter 1, as an introduction, provides the study background of this thesis, as well as an overview and the overall thesis structure and the relevance of each chapter.

In Chapter 2, summarizes infrastructure maintenance and management in local

governments, focusing on trends and data on bridge types for bridges in Aomori Prefecture as an example. It also summarizes opinions from practitioners in charge of actual infrastructure maintenance, and finds that road bridges in service in Aomori Prefecture are similar to the national trend and are relatively small in scale. In addition, against performing maintenance while keeping the existing bridge form, various existing studies, data, and research reports also indicated that if the bridge is divided into upper and lower structures, such as so-called girder and slab bridges, deterioration surveys and repair methods become complicated and inefficient due to personnel and budget constraints, and many expressed a desire for a simplified structure. Many of the respondents expressed a desire for a simplified structure. Even if it is a small-scale bridge, if it is a bridge, the inspection and maintenance management will be complicated.

Box culverts are expected as an alternative method for small-scale bridges. Utilization of precast products is expected to cope with the shortage of engineers and skilled workers.

In Chapter 3, in order to make the precast products described in Chapter 2 highly durable in snowy and cold regions, we examined highly durable concrete using blast furnace slag, which is widely used in western Japan, as well as blast furnace slag fine aggregate, blast furnace cement Class B, and Precast products were manufactured using precast aggregates used at a precast product manufacturing factory in Aomori Prefecture, and it was confirmed whether they have resistance to frost damage and salt damage. The results showed that the precast products have good durability .The results of this study showed that the use of this concrete in the precast products can produce precast products with high durability even in snowy and cold regions such as Aomori Prefecture.

In Chapter 4, since areal variation in quality is a concern in concrete products due to the increasing size of precast products, full-scale specimens were fabricated and non-destructive tests of simple air permeability and simple hydraulic conductivity tests were conducted to confirm areal distribution of concrete quality. The results showed that the areal variation of surface quality, which is a concern due to the larger size of the product, can be considered as one representative value by covering approximately 40% or more of the surface to be measured.

In Chapter 5, the integrity of precast products, especially large precast box culverts, in the direction of extension, which is a concern when they are used as an alternative method of construction for small bridges, is discussed.

The results of the study were also examined in the case of large longitudinal slopes, which have recently been observed in roadway boxes. The results showed that it is possible to ensure structural integrity by applying the optimum amount of PC tension according to the site conditions.

In Chapter 6, a sample site was investigated to see how much LCC and LCCO2 can be reduced when the large precast box culverts studied so far are actually constructed as an alternative construction method for small bridges. It was confirmed that the use of highly

durable precast products can reduce the total cost by approximately 50% compared to cast-in-place concrete structures, assuming a service life of 100 years, although the initial cost is about 1.5 times higher. In the social situation that infrastructure maintenance will face in the future, we described the usefulness of precast products and the need to promote environmentally friendly infrastructure maintenance.

While further research and resolution of issues specific to precast products in Chapters 3 through 5 of this study will naturally be necessary in the future, we believe it is particularly important to reflect and utilize the data, findings, and recommendations obtained in Chapters 2 and 6 in future infrastructure maintenance.

The cost of infrastructure maintenance is an extremely important factor, especially in local governments such as Aomori Prefecture, where a declining population is causing a shortage of workers. Various studies and simulations have shown that preventive maintenance can reduce the total project cost of bridge asset management compared to post-maintenance maintenance. However, although a shift to preventive maintenance is desired at the present time, we feel that initial costs are still the most important part of the project. This is a major point in infrastructure maintenance where there is not a complete shift to preventive maintenance.

Based on the actual situation of infrastructure maintenance in local governments obtained in this study, it is important that future infrastructure maintenance in local governments shift to preventive maintenance-type infrastructure maintenance that is efficient in many aspects, including durability, quality, construction, LCC, and SDGs, in order to maintain the infrastructure for the future lives of local residents. It is important to maintain the livelihood of local residents in the future.

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