

**“Technical Research and Development for Road Policy Quality Improvement”
Study Summary**

No.	Title	Principal Researcher
No.27 - 4	Development of the three-dimensional chloride penetration prediction method for the concrete bridges using mortar chip specimen and data assimilation technique	Niigata Univ. Prof. Tatsuhiko Saeki

A research and development that estimate the surface chloride concentration on all surfaces of concrete bridges under aerosol chloride condition, and predict the chloride penetration into concrete bridges and propose the maintenance scenarios using developed methods.

1. Backgrounds and Objects

In the management field of the concrete structures, it is thought that the design system to deal which is not uniform in line with the situation of individual structures is demanded. Therefore, the development of the concrete design methods such as the setting of the appropriate countermeasure and the rational setting in the range of measures is needed depending on individual conditions of structures such as age, environment of structure, load environment and construction quality.

This study aimed at development and the practical use of the design support tool of the concrete structures damaged due to chloride attack based on the mentioned above. The feature of this study is the fusion of the numerical analysis technology of the nondestructive monitoring technology with "mortar chip" (squared thin mortar) to put on the concrete surface.

2. Activities in Research Period

- a) Local observation of adhesion and penetration process of aerosol chloride: Exposure tests were carried out at 78 bridges (68 bridges in Niigata, 10 bridges in Okinawa).
- b) Improvement of production, put, collection method of the sheet mortar specimen
- c) Development of the program for aerosol chloride transportation process: Analysis method was formulated by the combination with fluid analysis and random walk method.
- d) Development of the inverse analysis program for aerosol chloride transportation: Inverse analysis method using a least-squares technique was developed.
- e) Development of the mass transfer program in the concrete
- f) Preparation of the guidelines for evaluation of chloride attack environment

3. Study Results

(1) Estimation method of chloride environment for durability design

- a) high precision estimation method of surface chloride concentration was formulated by considering altitude, direction of wind and wave energy.
- b) Simulations of the transport of aerosol chloride and adhesion of chloride on the surface of concrete structures under various wind conditions were carried out by the method of combination of fluid analysis and random walk method. Relative surface chloride concentrations on the surface of concrete structures were suggested from the results of these simulations.

(2) Estimation method of chloride environment for established concrete structures

- a) Early detection of part of high concentration of the surface chloride concentration by the "mortar chip" technique and preventive maintenance for these areas were proposed.
- b) The inverse analysis using the data from "mortar chips" and the direct analysis using the parameter decided by the inverse analysis were formulated to estimate of surface chloride concentration on various position of concrete structures.

4. Papers for Presentation

- 1) S. Yamashita, J. Tomiyama, K. Abe, T.Saeki and K.Kouro: Estimation of chloride on surface of concrete bridge by numerical simulation and inverse analysis, Proc. of the JSCE annual meeting, Vo.72,2017.9
- 2) S. Yamashita, J. Tomiyama, K. Abe, T.Saeki and K.Kouro: Estimate of adhesion amount of chloride ion on concrete bridge by 3-D numerical analysis considering wind directions, Proceedings of the Concrete Structure Scenarios, JSMS, Vol. 17 pp.609-614,2017
- 3) K. Akiyama, T. Saeki and S. Suzuki: Estimation of aerosol chloride condition in consideration with coastal conditions, Proc. of the JSCE annual meeting, Vo.73,2018.8

5. Study Development and Future Issues

An estimation method of surface chloride concentration for durability design was suggested. In addition, the surface chloride concentration at various positions of concrete bridge for durability design was proposed from the results of the simulation for aerosol chloride transport and adhesion. We will aim at the adoption of these methods to design standards in future. We aim at the social implementation and spread of the technique to apply preventive maintenance to the severe part of the damage from chloride attack environment decided by the measurement with the "mortar chip" for the time being.

In the estimation of chloride environment for the established structures, the methods of the inverse analysis using the exposure test results of "mortar chip" and the method of the estimation of the surface chloride concentration of the whole structure were developed.

We are going to make the bridge inspection efficient by using developed methods in cooperation with a construction consulting company.

6. Contribution to Road Policy Quality Improvement

- a) The "mortar chip" have been used by survey by Ministry of Land, Infrastructure and Transport.
- b) In the JSCE standard specifications for concrete structures [maintenance] 2018, the method of local environment with the mortar chip was described.

7. References, Websites, etc.

<http://www.eng.niigata-u.ac.jp/~doboku/project/index.html>