The Fifth International Conference on Railway Technology
RAILWAYS 2022
22–25 August 2022
Montpellier, France

Proceedings of the Fifth International Conference on
Railway Technology:
Research, Development and Maintenance
Edited by J. Pombo
Civil-Comp Conferences, Volume 1, Paper 10.17
Civil-Comp Press, Edinburgh, United Kingdom, 2022, doi: 10.4203/ccc.1.10.17

Simple On-site Evaluation Method for Cover-Concrete Quality of Horizontal Members by Spraying Water

S. Nishio

Material Technology Division
Railway Technical Research Institute, Tokyo, Japan

Abstract

To realize the construction of a concrete structure with excellent durability, from the viewpoint of concrete quality, it is necessary to provide a simple and cost-effective test method that can be used by practitioners. We have already proposed a water intentional spraying test (WIST), a simple non-destructive test method for cover-concrete quality. Although the WIST has been validated, applicable measurement sites have been limited to vertical members such as concrete walls. In this study, we have described a new measurement procedure and evaluation index for applying WIST to horizontal members such as concrete slabs. In the proposed method, a small amount of water is sprayed on the surface of the horizontal member. Immediately after the water spray, the gloss increases on the concrete surface where there are remains of water, and it gradually disappears due to water absorption. The presence or absence and disappearance of gloss is visually confirmed. The value of the gloss retention time after watering obtained visually is reduced for low quality concrete. In particular, the reduction of the gloss retention time due to early demolding is remarkable. The gloss retention time on the underside surface of the specimen had a variation coefficient of approximately 30% depending on the shape of the specimen. This study suggests that the weight change of the specimen increases in proportion to the height-to-depth ratio of the specimen. This is considered to be one of the causes for the error in the measurement result of the cover-concrete quality due to the scale and position of the measurement member. When applying non-destructive evaluation of cover-concrete quality to structures, it is necessary to assume that the coefficient of variation of measured values reaches approximately 30%. In the case where the gloss may

disappear in several seconds, the coefficient of variation increased, however, the author confirmed the possibility of evaluating the cover-concrete quality using the gloss retention time. In this study, the author has proposed a simple non-destructive test method for cover-concrete quality that used the gloss retention time rT as an evaluation index. In the evaluation of the cover-concrete quality based on the rT, differences in dimensions and shapes of concrete members affect measured value of rT. However, the fluctuations of these measured values don't hinder the classification of concrete of extremely poor quality. Quality assessment using rT contribute to the construction of highly durable structures and the reduction of maintenance costs.

Keywords: non-destructive test, durability of concrete structures, cover-concrete quality, permeability, water absorption, visual observation, water intentional spraying test.

1 Introduction

The durability of railway infrastructure, such as reinforced concrete (RC) viaducts, depends on the quality of concrete, which is a barrier to avoid rebar corrosion. In Japan, responding to an aging society is an urgent issue in all fields. Regarding the durability of RC infrastructure, there has been a growing movement to find effective ways to build durable infrastructure in order to reduce future maintenance work after construction. For example, in the middle of construction work, the on-site quality confirmation of hardened concrete has begun to be carried out by contractors.

In Japan, studies have proposed the Torrent permeability test [1] and surface water absorption test (SWAT) [2] as non-destructive testing methods for on-site evaluation of cover-concrete quality. Several cases have been reported in Japanese journals that quality improvement of newly built concrete structures has been achieved by utilizing quality evaluations by those methods. On the other hand, most users of these methods are researchers and specialists. The high cost of test equipment and the particularity of testing are barriers to practitioners in construction and structural management. To realize the construction of a concrete structure with excellent durability, not only the above-mentioned method but also a simple and cost-effective test method that can be used by practitioners is required.

The authors have developed a water intentional spraying test (WIST), a simple non-destructive test method for cover-concrete quality [3]. Using this method, the measurer evaluates the concrete quality by spraying a small amount of water onto a dry concrete surface with a manual sprayer and visually checking the state of water absorption. It has been confirmed that the evaluation index of WIST has a good correlation with the result of Torrent permeability test [4] [5] [6]. Although the WIST has been validated, applicable measurement sites have been limited to vertical surfaces such as the sides of walls and columns. In this study, we have described a new measurement procedure and evaluation index for applying WIST to horizontal surfaces such as underside of concrete slabs.

2 Methods

The experimental subject was the cover-concrete quality of the underside surface. The volume of the test specimens was unified at 4 liters each, and multiple types such as those with different heights of the test specimens were made of ready-mixed concrete with plywood formworks. The manufacturer provided ready-mixed concrete with following characteristics: nominal strength (30 MPa), slump (14 cm), air content (5.2%), cement type (ordinary Portland cement according to JIS R 5210), unit water (167 kg/m^3), and water-to-cement ratio (0.50). These values reflected the actual construction specifications of a railway RC viaduct. In this study, we prepared not only the above-described ready-mixed concrete (N-series), but also the concrete whose quality was deteriorated by adding water just before casting (L-series). The amount of water added was approximately 30 kg/m^3. Furthermore, to differentiate the concrete quality after hardening, we set the demolding time in two cases as 7 days (7D) and 1 day (1D). The test specimen was stored in a constant temperature and humidity test room after demolding (temperature of 20 degrees Celsius and relative humidity of 60%). Four days after demolding, we conducted WIST in the test room. The following four types of specimens were used to investigate the effect of the specimen shape: W200-D200-H100 mm, W100-D200-H200 mm, W100-D133-H300 mm and W100-D100-H400 mm. The compressive strength of the concrete was determined at 28 days of age using water-cured cylindrical specimens. Three specimens were used for each test.

In the WIST measurement, we sprayed pure water upward from the bottom surface of the concrete specimen. WIST requires periodically repeats a small amount of water spray at the same location using a dedicated test equipment. In this study, we sprayed water once in every minute, for a total three times. Immediately after the water spray, the gloss increases wherever water remains on the concrete surface. Such gloss due to water spray gradually disappears due to water absorption. The presence or absence and disappearance of gloss can be visually confirmed. In this study, after the spraying of water was completed, we checked “the gloss retention time, rT” visually and by a timer. The rT was obtained in 5 second increments. The outline of other conditions of this test is as follows: amount of water for each spraying was 0.10 g, the shape of watering area was circular, diameter of the watering area was 57 mm, watering area was 2550 mm^2.

3 Results

Table 1 shows the test results for each of the preparation conditions of the specimens: compressive strength, the characteristics of the gloss retention time rT. The compressive strength decreased by 23% due to early demolding. The rate of decrease in compressive strength due to water addition was 27%. The rT was significantly reduced in the early demold series. The coefficient of variation of the data is approximately 10% for the standard test case but increased in the early demold test case "L-1D".

Table 1: Test results.

Series of specimen	N-7D	N-1D	L-7D	L-1D
Compressive strength [MPa]	31.8	24.6	23.3	16.5
Gloss retention time rT				
The number of data	6	6	6	6
Minimum value [s]	600	30	260	5
Maximum value [s]	760	50	410	40
Mean [s]	676	41	345	18
Standard deviation [s]	66	8	51	17
Coefficient of variation [%]	9.7	19.6	14.7	92.4

Figure 1 shows the gloss retention time rT of specimens having different shapes. As a result of verifying the specimens with different heights by 100 mm with a constant volume and surface area per volume, the rT tends to be inversely proportional to the height-to-depth ratio (h/d). The coefficient of variation of the rT depending on the specimen shape was approximately 30%.

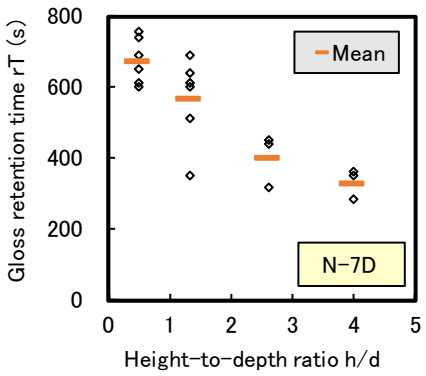

Figure 1: Relationship between gloss retention time and height-to-depth ratio.

Figure 2 shows a change in weight of the specimens having different shapes after demolding. The change in weight due to drying tends to increase in proportion to the h/d of the specimen.

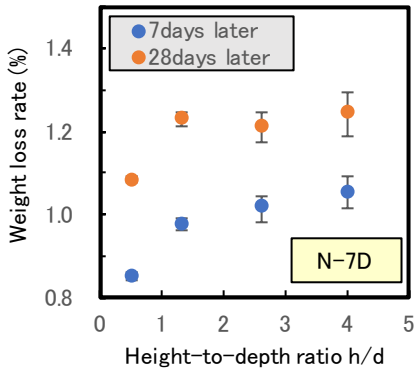

Figure 2: Relationship between gloss retention time and height-to-depth ratio.

4 Conclusions and Contributions

The value of the gloss retention time after watering obtained visually is reduced for low quality concrete. In particular, the reduction of the gloss retention time due to early demolding is remarkable. The gloss retention time on the underside surface of the specimen has a variation coefficient of approximately 30% depending on the shape of the specimen. This study suggests that the weight change of the specimen may increase in proportion to the height-to-depth ratio of the specimen. This is considered to be one of the causes of the error in the measurement result of the cover-concrete quality due to the scale and position of the measurement member. When applying non-destructive evaluation of cover-concrete quality to structures, it is necessary to assume that the coefficient of variation of measured values reaches approximately 30%. In the case where the gloss may disappear in several seconds, such as test case "L-1D" in this study, the coefficient of variation tends to increase, however, the possibility of evaluating the cover-concrete quality by the gloss retention time has been confirmed.

The author proposes in this paper a simple non-destructive test method for cover-concrete quality, WIST, which uses the gloss retention time rT as a new evaluation index. In the evaluation of the cover-concrete quality based on the rT, the measured values are affected by numerical fluctuations due to the dimensions and shape of the concrete member. However, the influence of such numerical fluctuations does not hinder the classification of concrete of extremely poor quality. Quality assessment by WIST with rT can contribute to the reduction of maintenance costs and the construction of highly durable structures. Finally, the measurement of the rT can be applied to the measurement surface in all directions. When comparing the measurement results under the condition that the direction of the measurement surface is different, correction of the measurement value is necessary, however it is not in the scope of this study.

References

[1] R. J. Torrent, “A two-chamber vacuum cell for measuring the coefficient of permeability to air of the concrete cover on site”, Materials and Structures, 25, 358-365, 1992.

[2] U. Akmal, K. Hayashi, A. Hosoda, K. Suhara, “Evaluation of covercrete of expansive concrete with external restraint by surface water absorption test”, Proceedings of the Japan Concrete Institute 34, 760-765, 2012.

[3] S. Nishio, “Simple evaluation of water permeability in cover concrete by water spray method”, Quarterly Report of RTRI, 58(1), 36-42, 2017.

[4] M. H. Nguyen, K. Nakarai, Y. Kubori, S. Nishio, “Validation of simple nondestructive method for evaluation of cover concrete quality”, Constr. Build. Mater., 201, 430–438, 2019.

[5] M. H. Nguyen, K. Nakarai, S. Nishio, “Durability index for quality classification of cover concrete based on water intentional spraying tests”, Cement and Concrete Composites, 104, 103355, 2019.

[6] M. H. Nguyen, K. Nakarai, Y. Kai, S. Nishio, “Early evaluation of cover concrete quality utilizing water intentional spray tests”, Constr. Build. Mater., 231, 117144, 2020.