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Evaluation of Surface Layer Quality Using a Simple Ultrasonic Velocity Measurement

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ABSTRACT

In recent years, the quality of the surface layer of constructed concrete has been confirmed by testing at the new construction stage. However, these tests have the problem that the measurement time is long and is affected by the moisture content of the concrete during the measurement. Therefore, there is a need for a method to investigate the surface quality of concrete accurately and in a short time. The purpose of this study is to determine the quality of concrete surface layer by using ultrasonic velocity obtained by a lightweight ultrasonic velocity measuring device. Therefore, the measurement was carried out by changing the conditions of concrete. As a result, the porosity has a greater influence on the variation of ultrasonic velocity than the water cement ratio or the amount of coarse aggregate. The ultrasonic velocity increased in the scope of this study when the voids inside the concrete contained water.

KEYWORDS: *surface quality, Ultrasonic, Moisture content, porosity*

1. Introduction

In order to ensure the durability of concrete structures, it is necessary to improve the surface quality of concrete. When the surface quality of concrete is deteriorated, the degradation factors such as CO_2 and Cl^- penetrate into the concrete from the surface, causing corrosion of steel bars. In recent years, the surface quality of concrete has been investigated at the new construction stage, and simple air permeability tests and simple water absorption tests are mainly used. However, these tests require a long measurement time and are affected by the water content of the concrete during the measurement. Therefore, there is a need to capture the surface quality easily and accurately.

In this study, a simple evaluation of the quality of concrete surface layer was attempted by using the ultrasonic velocity obtained from a handheld ultrasonic velocity measuring device as shown in Figure 1. It is reported that the ultrasonic velocity obtained from the ultrasonic velocity measuring device depends on the strength. However, in the surface layer, mass transfer resistance is considered to be important. In this study, we focused on the aggregate, paste, and voids that make up the concrete, and since ultrasonic waves penetrate the interior of concrete, these properties were varied for measurement. In this study, we focused on the aggregate, paste, and voids in concrete. In order to investigate whether the ultrasonic velocity is affected by the amount of water retained in the specimen, the specimen was allowed to absorb water and the surface water content at the time of measurement was compared.

Figure 1. Ultrasonic velocity measurement system

Table 1 Mix proportion

W/C	s/a	Unit weight(kg/m^3)			
		Water	Cemant	Sand	Aggregate
40%	40%	170	425	677	1054
	45%			761	966
	50%			846	878
55%	48%		309	864	947
60%	40%		283	723	1126
	50%			814	1033
	60%			904	939

2. Outline of experiments

2.1. Materials and specimen specifications

The planned mix proportions of the concrete are shown in Table-1. Ordinary Portland cement was used as the cement. After curing in water for 7 days, the concrete was placed in a constant temperature and humidity environment and the ultrasonic velocity was measured at 28 days of age. In order to understand the effect of coarse aggregate and paste on the ultrasonic velocity, three types of fine aggregate (40, 45, and 50%) were prepared at water-cement ratios of 40% and 60%. In order to investigate the relationship between the porosity and the ultrasonic velocity, the porosity and the ultrasonic velocity were measured using a mixture with a water cement ratio of 40% and a fine aggregate ratio of 45%, and another mixture with a water cement ratio of 55% and a fine aggregate ratio of 48%. In order to change the water holding capacity of the specimens, the specimens made with the 55% water-cement ratio were allowed to absorb water for 7 days after drying, and the changes in surface water content and ultrasonic velocity were measured. The dimensions of the specimens were 100 x 100 x 400 mm.

2.2 Ultrasonic velocity measurement

Figure 1 shows the ultrasonic velocity measurement system used in this study. Ultrasonic velocities were measured twice at the center of two sides of the specimen and the average value was calculated.

2.3 Moisture content measurement test

The water content of the specimens after the water absorption was completed was measured by ultrasonic velocity measurement and the same part of the measurement, and the measurement was carried out using mortar and concrete moisture meter.

2.4 Porosity measurement test

The porosity was calculated by Archimedes method. The test specimens were depressurized by a vacuum pump for 6 hours to make them water-saturated. The weight of water-saturated specimens after the water-saturated treatment and the weight of water-saturated specimens were measured, and the porosity was calculated by the following equation (1).

$$\text{porosity ratio (\%)} = \frac{W_1 - W_2}{W_1 - W_3} \times 100 \tag{1}$$

W_1 : Weight of saturated water(g)
W_2 : Dry weight(g)
W_3 : Underwater weight(g)

3. Results and discussion

3.1 Relationship between coarse aggregate and ultrasonic velocity

Figure 2 shows the relationship between coarse aggregate ratio and ultrasonic velocity. ultrasonic velocity increased as the unit volume percentage of coarse aggregate increased in both W/C40% and W/C60%, and the effect of the paste portion (water cement ratio) was also confirmed.

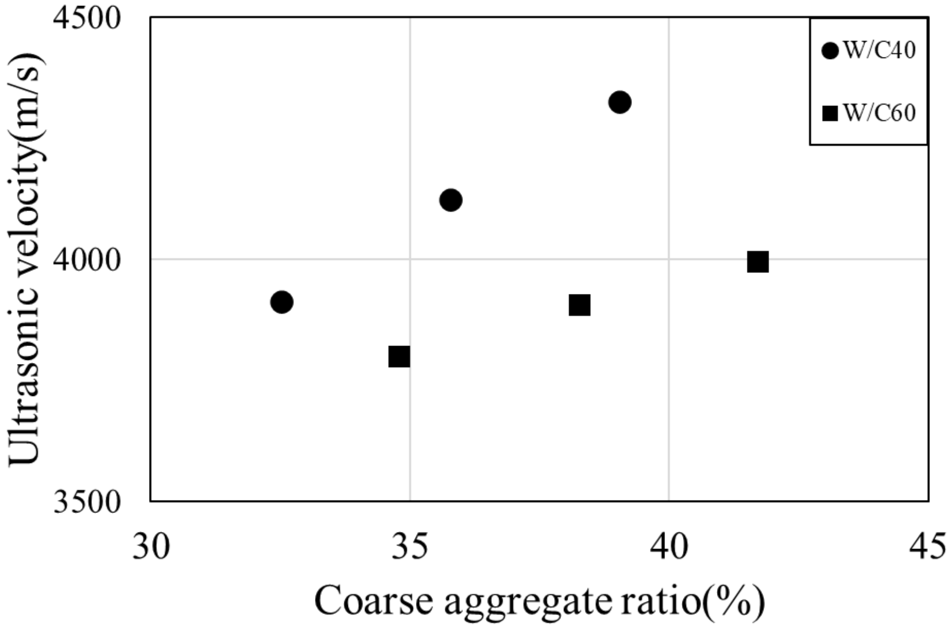


Figure 2 Specimen Volume Percentage of coarse aggregate and ultrasonic velocity

3.2 Relationship between porosity and ultrasonic velocity

The relationship between the porosity and ultrasonic velocity of concrete is shown in Figure 3. As the porosity increased, the ultrasonic velocity decreased. The denser the concrete with less porosity, the higher the ultrasonic velocity.

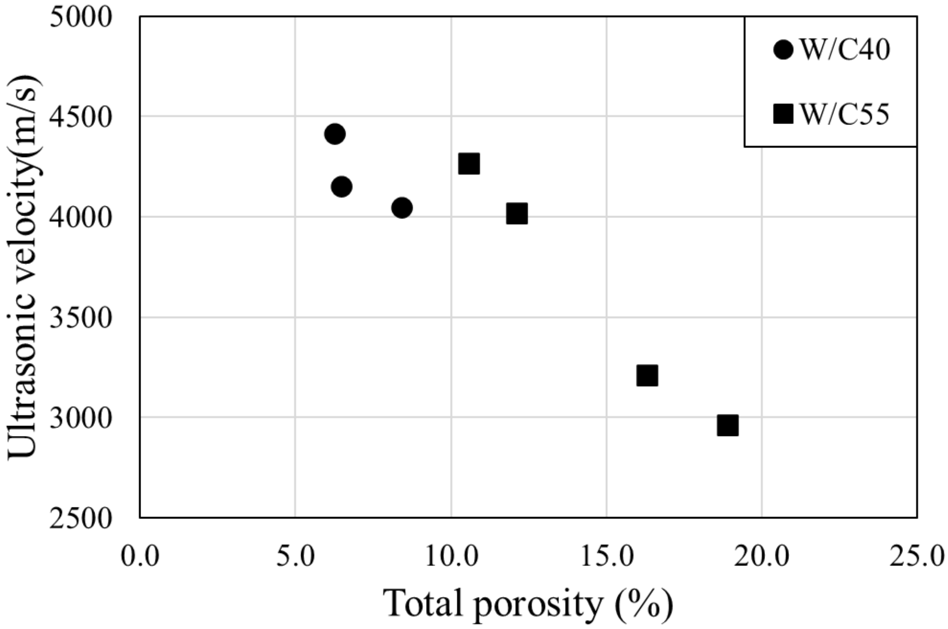
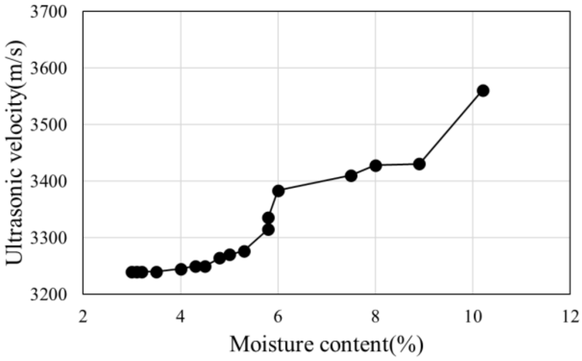


Figure 3. Porosity and ultrasonic velocity

3.3 Relationship between moisture content, mass loss rate and ultrasonic velocity

Figure 4. shows the relationship between surface moisture content and ultrasonic velocity. The ultrasonic velocity decreased as the moisture content decreased, but the variation of the ultrasonic velocity was not linear and a sharp decrease was observed, and the decrease of the ultrasonic velocity became slow when the moisture content was below 5.5%. The decrease in ultrasonic velocity became slower when the moisture content dropped below 5.5%. This is thought to be due to the fact that the drying of the surface layer of concrete does not proceed uniformly, but rather the moisture content in the void changes with depth and the drying progresses. Figure 5. shows the relationship between the mass loss rate and the ultrasonic velocity. The decrease in ultrasonic velocity became slower when the mass loss rate exceeded 2%. This is thought to be due to the evaporation of water in the surface layer, which affects the ultrasonic velocity.



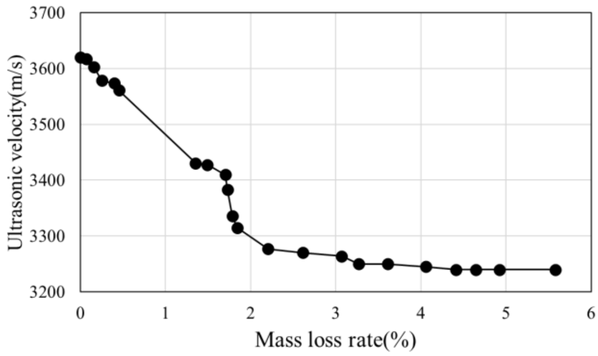


Figure 4. Moisture content and ultrasonic velocity   Figure 5. Mass loss rate and ultrasonic velocity

4. Conclusion

The relationship between coarse aggregate, porosity and ultrasonic velocity is summarized as follows: the amount of change in ultrasonic velocity caused by an increase in porosity is larger than the change in coarse aggregate unit volume fraction or paste portion.
From the relationship between water content, mass loss rate and ultrasonic velocity, the ultrasonic velocity increases in the range of this study when the voids inside the concrete contain water.
The ultrasonic velocity through the concrete is considered to be in the order of aggregate, paste, then water-filled voids, and finally water-free voids.
However, in this study, only one type of specimen was used to understand the relationship between the moisture content, mass loss and ultrasonic velocity, so it is possible to develop a practical evaluation method by examining the relationship between the moisture content, mass loss and ultrasonic velocity of specimens with different porosity. Therefore, it is possible to develop a practical evaluation method by examining the relationship between the water content, mass loss and ultrasonic velocity of specimens with different porosity.

5. Future works

In this study, the effects of ultrasonic velocity on changes in coarse aggregate fraction, water cement ratio, porosity and water holding capacity of concrete surface layer were investigated. The effect of ultrasonic velocity on the changes in coarse aggregate ratio, porosity and water holding capacity of concrete surface layer was investigated. At the present stage, it is not possible to evaluate the quality of the surface layer and can only predict the areas of deterioration.
In the future, the quality of the surface layer of concrete will be investigated by investigating how deep the measuring range is from the surface, and by evaluating the concrete surface layer using ultrasonic velocity and water absorption testing machine (SWAT).

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