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Study on Indexes of Aggregate Quality to Evaluate Freeze-thaw Resistance of Concrete Produced

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ABSTRACT:
This paper discusses the applicability of a quality evaluation test method proposed for dam concrete aggregates. From a view point of freeze-thaw resistance performance in concrete, this paper suggests a simplified test method that can provide criteria for selecting an aggregate that provides freeze-thaw resistance performance. The simplified test method suggested in this paper provides direct freeze-thaw action to the aggregate.
The results are as follows. The test method enables proper evaluation for gravel. Yet, when using crushed stone aggregate, evaluation based on a simplified test method does not necessarily give proper result; rather, it is more desirable to make decisions based on water absorption of the aggregate.

Keywords: Low quality aggregate , Freeze-thaw resistance , New simple test method , Water adsorption

1. INTRODUCTION

Construction of a concrete dam requires a large amount of aggregate. Gravel found near dam sites and crushed stones obtained by excavating mountains are used as aggregate. Proper evaluation of aggregate properties is needed to use such aggregate effectively.

Aggregate quality greatly affects the freeze-thaw resistance of concrete. In Japan, the soundness test with sodium sulfate is usually used for the evaluation of aggregate quality. Yet, as shown in Fig.1, the relationship between the weight loss of the soundness test and the durability factor against freezing and thawing action of concrete that uses the tested aggregate is unclear. Thus, validity of the evaluation of aggregate quality based on the soundness test is questionable. Therefore, this study examines a simplified test method that imposes direct freeze-thaw action to the test sample of aggregate as an alternative method to the soundness test.

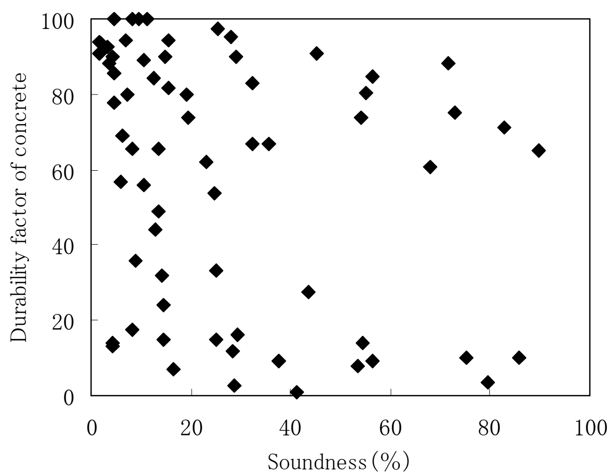


Figure 1. Outcome of soundness test with coarse aggregate and relationship with durability factor of concrete

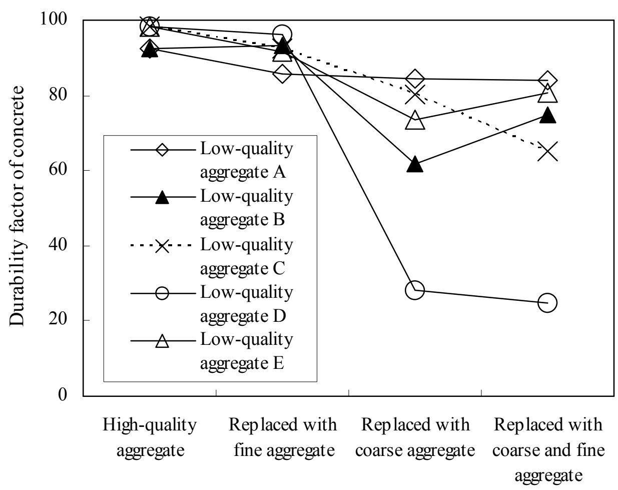


Figure 2. Effect of fine aggregate and coarse aggregate on durability of concrete

The scope of the test method is coarse aggregate. The reason for this is that fine aggregate has small effects on the freeze-thaw resistance of concrete while the effect of coarse aggregate is large. Durability factor of concrete produced with using low quality aggregate(A to E) is shown in Fig.2. Using low quality coarse aggregate can affect durability of concrete more seriously than low quality fine aggregate.

2. TEST METHOD

2.1. Simplified Freeze-thaw Test for Coarse Aggregate

The simplified freeze-thaw test for aggregate is a test method that our study team has developed to evaluate the freeze-thaw resistance of recycled aggregate. Fig. 3 shows the outline of the test. Testing procedure is described below.

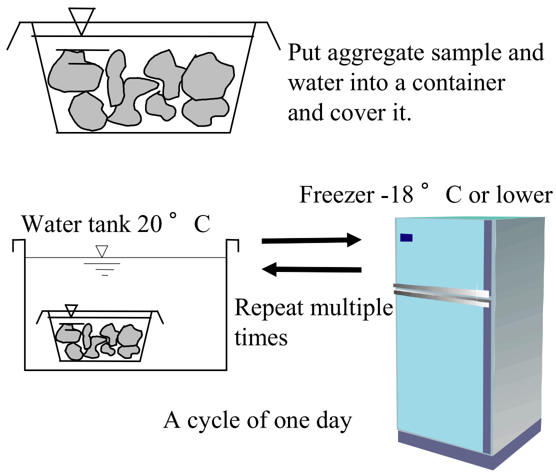


Figure 3. Simplified freeze-thaw test for coarse aggregate

1) Sift and sort coarse aggregate into particle sizes of 25 to 20 mm and 20 to 15 mm.

2) Put about 1 kg of the sorted coarse aggregate into a polypropylene container of about 1,000 cc and fill it with water.

3) Let the aggregate undergo freeze-thaw action by putting it in a freezer and then in the water tank for a cycle of one day.

4) After completing a designated cycle, take the aggregate out of the container and let it air dry.

5) Measure the ratio of particles that fell from the screen/sieve used before the test (loss ratio).

To accelerate deterioration during the freeze-thaw process, a test involving salt water in which sodium chloride (NaCl) was mixed with water at the mass ratio of 1% was also conducted.

2.2. Coarse Aggregate Studied in the Test

27 types of coarse aggregate were gathered from many areas of Japan. Some of the aggregate gathered did not satisfy quality standards. The quality standard for aggregate used in dams in Japan requires a water absorption rate of 3.0% or less and the weight loss of the soundness test must be 12% or less.

The coarse aggregate was studied by categorization into crushed stone (16 data) and gravel (11 data). This is because crushed stone and gravel have the following differences:

Crushed stone: Produced in crushed stone quarries. The variation in quality among aggregate particles is small, since the aggregate is produced by crushing relatively homogeneous bedrock. The particles are angular because stones are crushed to produce the aggregate.

Gravel: Riverbed deposit from rivers or areas that used to be rivers. Riverbed deposit accumulates on a river as rocks fallen from mountains along the river flow down the river over many years. Thus, riverbed deposit consists of various types and qualities of rocks. Due to the friction caused by the flowing river, the particles are rounded.

3. THE TEST RESULT

3.1. Evaluation of the Gravel

The outcome of the simplified test for gravel (30 cycles) is compared with the durability factor of the concrete containing the gravel (W/C 55%, Air 4.5%).

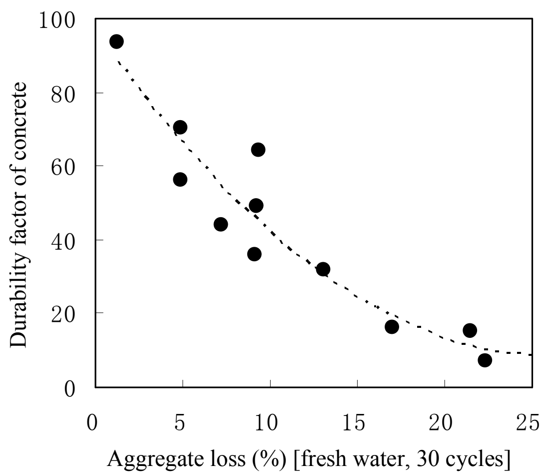


Figure 4. Relationship between the outcome of the simplified test for gravel and the durability factor of concrete (fresh water, 30 cycles)

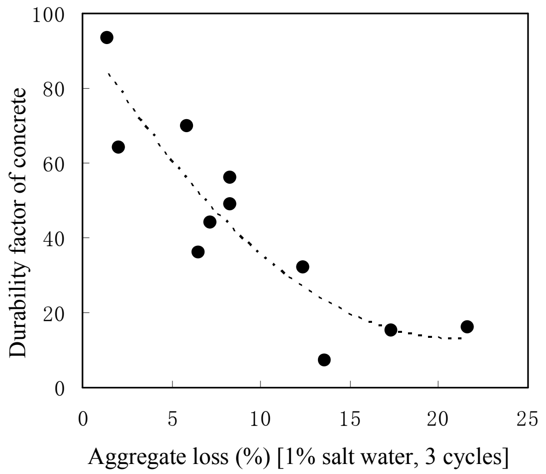


Figure 5. Relationship between the outcome of simplified test for gravel and the durability of concrete (1% NaCl solution, 3 cycles)

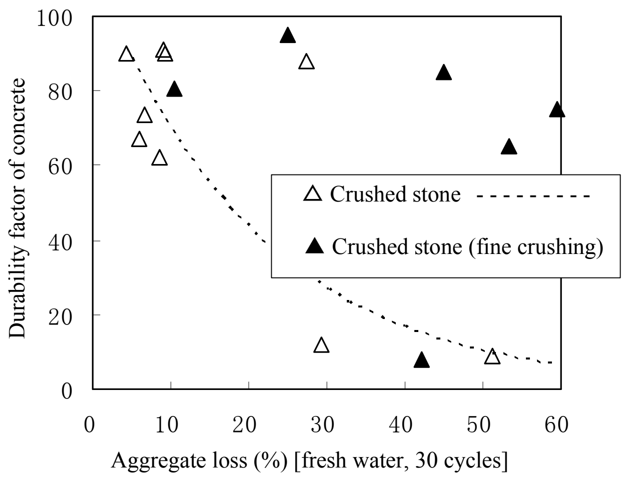
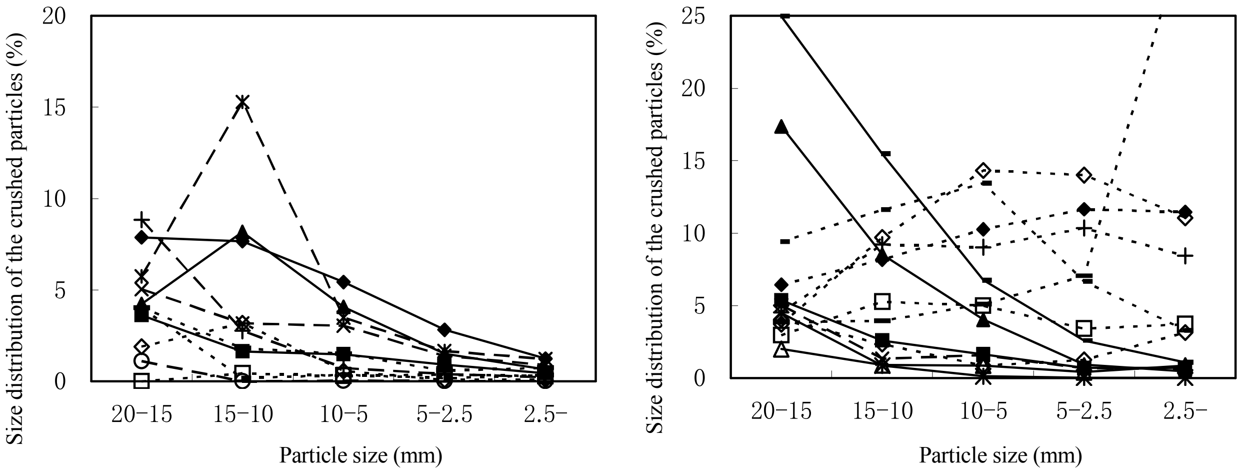


Figure 6. Relationship between the outcome of the simplified test for crushed stone and the durability of concrete (fresh water, 30 cycles)



(1) Outcome of the gravel of 20 to 25 mm

(2) Outcome of the crushed stone of 20 to 25 mm

Figure 7. Distribution of the size of particles crushed in the simplified test

Fig. 4 shows the relationship between the durability factor and the weight loss of aggregate by the simplified test.

The weight loss of the simplified test for gravel showed a good correlation with the durability factor of the concrete.

Gravel consists of various types of rocks. The durability factor is thought to be dependent on the percentage of low quality particles in aggregate sample. The simplified test proposed in this paper can well estimate the percentage.

As a measure to reduce the number of repeat cycles in the simplified test, a 1% NaCl solution was used in the test. Fig. 5 shows the outcome. A relatively good result was obtained only after running three cycles.

3.2 Evaluation of Crushed Stone

The applicability of the simplified test is compared for the case of crushed stone (30 cycles) and the concrete containing the crushed stone (W/C 55%, Air 4.5%). Fig. 6 shows the result. The simplified test for crushed stone did not show a good correlation with the durability factor of concrete. The reasons for this are discussed below.

Fig. 7 shows the distribution of particles crushed during the simplified test. Compared to the test for gravel, the test for crushed stone involved more cases in which the ratio of fine particles increases (the data shown with a broken line in the diagram).

Fig. 8 shows an image of such deterioration. The deterioration of the gravel involved cracks inside the gravel aggregate. In the meantime, deterioration of crushed stone, scaling is expected to progress first on

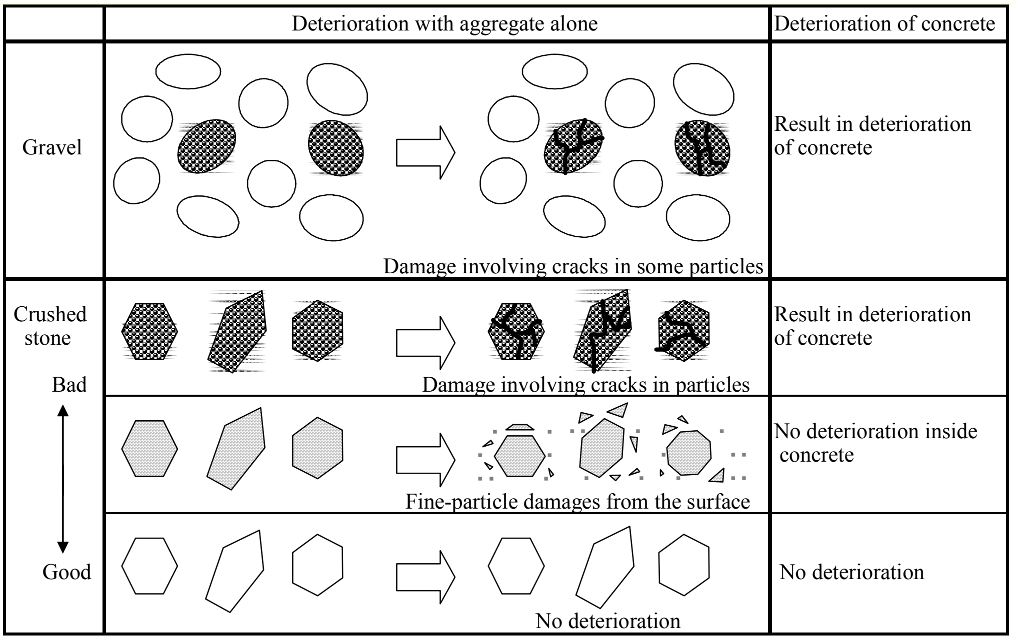


Figure 8. Relationship between the deterioration of aggregate and deterioration of concrete (image)

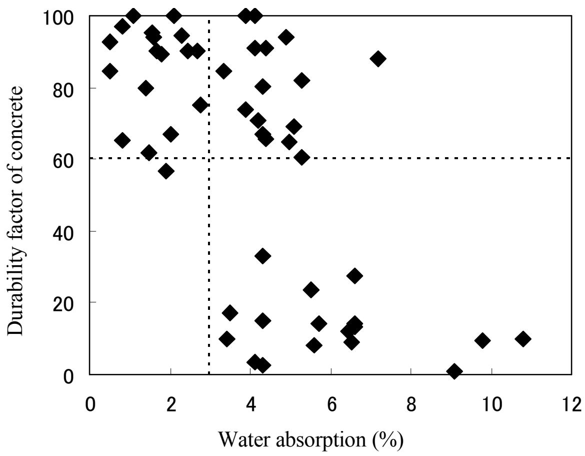


Figure 9. Relationship between the water absorption of the crushed stone and the durability factor of concrete

the surface of the aggregate. Since the scale of such deterioration on the surface is small, such deterioration is unlikely to occur inside concrete that is completely covered with cement paste.

In Fig. 6, the symbol ▲ represents such deterioration. Removing it resulted in a good correlation between the outcome of simplified test for the crushed stone and the durability factor of concrete.

Nonetheless, it is not easy to evaluate the durability of concrete containing crushed stone based on simplified tests.

Fig. 9 shows the relationship between the water absorption of crushed stone (51 data) and the durability factor of concrete. The durability factor was 60% or more when the water absorption was 3% or less, showing a good correlation. Unlike with gravel, crushed stone is less variation in quality between the particles. This is probably the reason that it showed a good correlation with the water absorption rate, which indicates an average porous level.

4. CONCLUSION

(1) The simplified freeze and thawing test for the gravel aggregate gives good estimation of the durability factor of concrete with using gravels as coarse aggregate.

(2) Using 1% NaCl enables reduction of the number of freezing and thawing cycles of the simplified test.

(3) The simplified test method is not applicable for the crashed stone aggregate which deteriorate with scaling by freezing and thawing cycles.

(4) The water absorption of coarse aggregate and the durability factor of concrete with using crushed stone as the coarse aggregate showed a good correlation. This means that the water absorption is better indexes than the weight loss of the simplified test in case of the concrete produced with crashed stone as coarse aggregate.

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