Stability evaluation of concrete erosion control dam using nondestructive test

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1. Introduction

Concrete erosion control dam often suffers the problem such as deterioration of durability caused by poor material or workmanship and the partial cracks results in structural collapse in part or whole and loses its function as erosion control dam. Should such safety problem with the structure be monitored at early stage, repair and maintenance of the dam could be implemented in timely manner, thereby maximizing the disaster-prevention function of erosion control dam. Concrete nondestructive test has been commonly used to estimate the concrete strength or for safety diagnosis. Estimate of concrete strength using nondestructive test is aimed at determining whether the structure satisfies the strength requirements in specification. Concrete nondestructive test is categorized into impact method, vibration method and combined method. Impact method is again divided into surface hardness and rebound hardness, and vibration method includes sonic method and resonance method, and combined method includes sonic and rebound hardness method, sonic and sonic attenuation. In this study, rebound hardness method categorized into impact method was used for nondestructive test. Though rebound hardness test is limited to the surface of the structure, measuring is easy and highly applicable and thus has been commonly used. Concrete nondestructive test in advanced countries has a long history. However, in Korea, safety assessment of the structure has been implemented since 1990s and despite of different construction environment from the foreign countries such as diagnosis and assessment techniques, the formula to estimate the rebound hardness considering our own environment has yet to be developed and the formulas we have been using are mostly from Japan (The Meterials Research Society of Japan (MRS-J), Tokyo Building Materials Test Institute (Tokyo), Architectural Institute of Japan (AIJ)) and other nations. In this study, rebound hardness of upstream face, drainway and downstream face was measured using "Concrete test Hammer" at 6 dams in good conditions and 4 dams in poor conditions among the erosion control dams built in 1990s in Gyeonggi Province and Gangwon Province as designated by The Korean Association of Soil and Water Conservation, and then concrete compressive strength was calculated after applying correction value. The purpose of this study is based on analysis of the compressive strength of erosion control dams, stability of the dams built in 1990s was evaluated and the appropriate scope of judgment by nondestructive test was determined.

2. Materials and Methods

2.1 Testing Materials

The specimen was taken from 6 dams evaluated to be in good conditions and 4 dams in poor conditions among the erosion control dams built in 1990s. As the water absorbs, deflects or reflects the acoustic wave, the test was carried out at the dam where the water did not overflow.

2.2 Measuring Rebound Hardness (R)

Rebound hardness of drainway, upstream face and downstream face of the erosion control dam was measured using concrete test hammer(Model a-750RX). When it comes to hammering, 99% of reliability could reportedly be achieved with 15 times or more on column, wall and girder. Accordingly, hammering was done 20 times at least per point in this study. For drainway, rebound hardness was measured at 1m or 2m interval depending on size of the body from the point where dam shoulder and the body contacts to the dam shoulder on opposite side, and for upstream face and downstream face, rebound hardness was measured at 3 points on both dam shoulders and the center of the body.

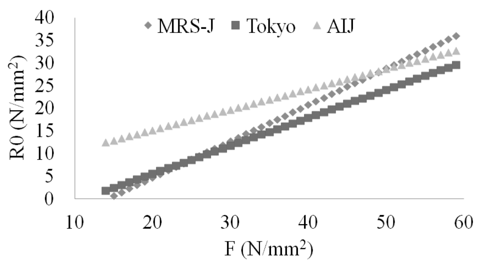


Fig 1. Three formulas of measuring compressive strength of Japan

2.3 Measuring Compressive Strength (F)

Rebound hardness method is called "Schmidt Hammer" which is a simple strength measuring method without damage to the structure and has been widely used worldwide. Schmidt Hammer is designed to indicate the rebound hardness (R) depending on impact energy when hammering the hardened concrete surface with Schmidt Hammer and the correlations between rebound hardness and compressive strength is calculated to estimate the strength of concrete structure. In Japan, three formulas are recommended but the slight differences among the formulas. The formula to estimate the compressive strength from the standard rebound hardness (R0) is indicated in Fig 1. Standard rebound hardness (R0) was calculated by applying the correction value (△R) to measured rebound hardness.

2.3.1 Correction value 1: Impact angle

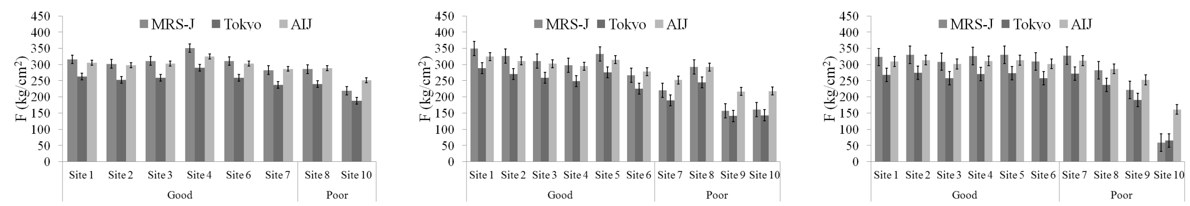
For upstream face and downstream face, rebound hardness was measured in horizontal direction and the correction value 0 was applied, while drainway was measured vertically and correction value was applied considering the impact angle (α=-90°; $Y = 0.0001R^2 + 0.689R - 6.848$).

2.3.2 Correction value 2: Curing age

In this study, the dams were built in 1990s, correction value 0.63 corresponding to the oldest one, 3,000 days was applied.

3. Result and Evaluation

Except site #5 and #9 which were filled with the sand, compressive strength of upstream face of the dam at 8 sites was measured and the compressive strength at the site #1, #2, #3, #4 and #6 in good conditions which were measured in accordance with the formulas of Materials Research Society Japan, Tokyo Building Materials Test Institute, Architectural Institute of Japan and as a result, they were 318.0kgf/cm^2, 264.5kgf/cm^2 and 306.6kgf/cm^2, respectively and the site #7, #8 and #10 which were measured 262.3kgf/cm^2, 221.7kgf/cm^2 and 275.4kgf/cm^2, respectively. Compressive strength of drainway of the dam at 6 sites in good conditions which were measured in accordance with the formulas of Materials Research Society Japan, Tokyo Building Materials Test Institute, Architectural Institute of Japan and as a result, they were 313.7kgf/cm^2, 261.2kgf/cm^2, 304.2kgf/cm^2, respectively and the 4 sites in poor condition which were measured 207.6kgf/cm^2, 179.6kgf/cm^2, 244.7kgf/cm^2, respectively. Compressive strength of downstream face of the dam at 6 sites in good conditions which were measured in accordance with the formulas of Materials Research Society Japan, Tokyo Building Materials Test Institute, Architectural Institute of Japan and as a result, they were 312.2kgf/cm^2, 266.9kgf/cm^2, 308.4kgf/cm^2, respectively and the 4 sites in poor condition which were measured 222.5kgf/cm^2, 191.0kgf/cm^2, 253.1kgf/cm^2, respectively.



Upstream face | Drainway | Downstream face

Fig 2. Compressive strength of upstream face, drainway and downstream face on 10 sites

Results of the compression strength investigation express that there is a consistency with visual inspection of stability that has been processed by The Korean Association of Soil and Water Conservation. We concluded that a prediction equation, which was developed by Architectural Institute of Japan, shows highest suitability in Korean erosion control dams when stability investigation is performed. The detailed criteria for the test result are 'Good (or Stable)', 'detail inspection required' and 'Poor' for over 300kgf/cm^2, 250~300kgf/cm^2 and below 250kgf/cm^2 respectively. Standards for stability of Korean erosion control dam and a compression strength prediction equation (that corresponds to the standards of the stability) should be established on the basis of chronological data of erosion control dam compression strength. Systematical approach for stability inspection that carries out remodeling or repair when problem on erosion control structures are detected through visual inspection and simple stability test, is necessary for the future disaster prevention.