Japan's 100-year-Old Otaru Port Breakwater: the Longest Durability Test in the World

The history of concrete is surprisingly long, with some dating its origin to ancient Greek and Roman times. Recent research, however, suggests that concrete is older still, and may have been discovered around 7000 B.C. during the New Stone Age.

The modern history of cement began with Joseph Aspdin, a British brick worker, who in 1824 invented and patented a method for producing hydraulic cement. About half a century later, in 1875, cement was successfully produced in Japan. Thus, the history of cement production in Japan is only a little more than 100 years old.

In recent years, the early deterioration of concrete structures has become a major problem. Concern is growing about the durability of concrete, which depends not only on the quality of the concrete, but also on environmental conditions. Laboratory studies, however, usually take place under highly controlled conditions, making it difficult to predict the actual performance of concrete in a real environment. Moreover, the various acceleration tests that evaluate the long-term durability of concrete are rarely correlated with the performance of concrete in the actual environment. Despite the huge amount of data available from a variety of studies, little real information exists on the long-term durability of concrete.

To evaluate the real durability of concrete, it is necessary to observe actual concrete structures over a long period. This is difficult to do; continuous evaluations are almost impossible. Evaluations using specimens are relatively easy, but long-term testing requires the efforts and patience of many people. Nonetheless, several remarkable projects have been designed to study the long-term durability of concrete. The University of Wisconsin-Madison in the United States, for instance, has been carrying out tests since 1910, and has so far reported the results on the compressive strength of concrete up to 50 years old. In 1936, the U.S. Army Corps of Engineers began exposure tests of concrete specimens at Treat Island, Maine. Unfortunately, this project has not kept continuous records on the strength of concrete.

Prior to these two projects in the United States, a durability test of concrete was begun at the port of Otaru, Japan, in 1897. This test continues to this day, making it the longest-running test in the world. In addition to evaluating concrete durability, the 100-year-old Otaru project is testing concrete mix proportions and evaluating the tensile strength of mortar.

Break waters at Otaru Port

Otaru is located about 30 km northwest of Sapporo on the Japan Sea. Opened in 1899, the port (Photo 1) was constructed in two phases, the first from 1897 to 1908 and the second from 1908 to 1921. Concrete technology at that time was underdeveloped. Abrams' theory on the water-cement ratio would not be published until l918, and air-entraining agents would not be introduced in Japan until 1948. It was under these circumstances that, in 1894, Dr. Isamu Hiroi (1862-1928, Photo 2), a professor at the Sapporo Agricultural College and an engineer for the Hokkaido government, assumed responsibility for the Otaru port construction project.

Aerial View

Close-up View of Breakwater

Photo 1 Otaru Port

Photo 2　Dr. Isami Hiroi (1862-1928)

Hiroi went to the United States at his own expense in 1883 and became engaged in both river improvement work on the Mississippi River and the design of bridges. He also studied hydraulic technology in Germany. In 1888, he published a famous book on steel bridge design, “Plate Girder Construction (Van Nostrand).” In 1899 he returned to Japan and became a professor at Tokyo Imperial University (The University of Tokyo).

At Otaru port, Hiroi carried out tensile strength tests on mortar specimens. The results of the tests were used to select concrete materials for the breakwaters. A decision in 1920 to use volcanic ash was crucial. Based on the results of tensile strength tests on mortar specimens up to 22 years old, he concluded in 1922 that the silica-rich volcanic ash found in Otaru developed strength more effectively than volcanic ash found elsewhere. Moreover, he concluded that volcanic ash offers superior strength and durability when mixed with cement in the proper proportions.

100 Year Durability Test

Production of the mortar specimens started in 1896—one year before construction of the north breakwater began—and continued until 1937. These specimens were gourd-shaped (Photo 3). A few 70 mm (2.8 in.) cubic specimens were also made (Photo 4); some were used for compressive tests, but most were used for tensile strength tests.

Photo 3　Gourd-shaped Specimens

Photo 4　Cubic Specimens