CS-234

ADVERSE GEOLOGICAL CONDITIONS AND THEIR IMPACTS ON CONSTRUCTION PROGRAM AND COST FOR OVERSEAS DAM PROJECT

Hiroshi FURUBE, Fellow, HAZAMA Corporation
Tetsuo IGARI, Member, HAZAMA Corporation
Akira NISHIO, HAZAMA Corporation

1. Introduction

The Bili-Bili Multipurpose Dam was constructed on the Jeneberang River approximately 31km southeast of Ujung Pandong, South Sulawesi, Indonesia, which was financed by OECF. The Bili-Bili Dam consists of three rockfill dams with central earth core for left wing dam, main dam and right wing dam. The dams are approximately 75m high at the maximum section and have approximate crest lengths of 1,800m, and the total embankment volume is around 6.2million m^3.

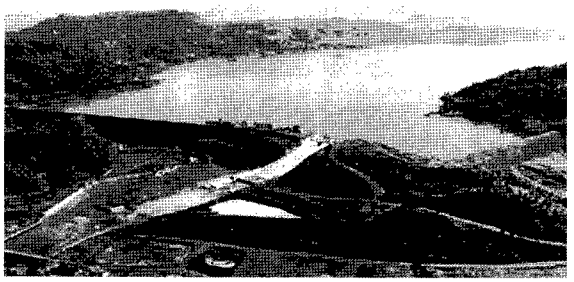

Photo 1 The general view of the Bili-Bili Multipurpose Dam.

The dam construction was commenced in January 1994 and was completed in November 1997. **Photo 1** shows the general view of the completed dams and the reservoir area.

During the execution of the works, the Contractor encountered several physical conditions, especially geological problems which could not be reasonably foreseen before the commencement of the works although he studied geological information based on the pre-investigation. This report introduces the unanticipated geological problems that adversely influenced the Contractor's construction program and cost performance.

The following two major geological problems occurred in this project :

(1) Repeated Excavation and Treatment to secure Suitable Dam Foundations

(2) Shortfall of Rock Material from Rock Quarry

2. Geological Phenomena and Impacts to Works

Diabase, intrusive igneous rock, was widely distributed in all dams, spillway and rock quarry. The intrusive dike rocks of Diabase featured the extraordinary geological phenomenon as follows :

① Diabase was generally hard and fresh when excavated and exposed. However, some rock masses had a tendency to weather easily and disintegrate into sand-like in a few weeks.

② Massive rock masses of Diabase had cracks and joints that gradually develop and open. Opening of cracks was found in foundation where grouting had been conducted as shown on **Photo 2**.

Fig.1 shows the monitoring results of the opening of cracks in Diabase foundation of dams.

To treat the above geological phenomena encountered in the dam foundations, several measures such as additional excavation, shotcrete protection, slush grouting, backfill concrete and re-grouting were carried out. Furthermore, in the rock quarry, the rock surface lines were actually quite lower than those initially estimated and quantity of suitable rock materials was decreased drastically. Consequently, the Contractor had to remove substantial volumes of unsuitable materials from the quarry and extend the quarry area to obtain adequate quantities of rocks.

Keywords: rockfill dam, geology, diabase, chemical reaction, adverse physical condition, contractor's risk
2-5-8, Kita-Aoyama Minato-ku, Tokyo, 107-8658. Tel:03-3405-4052, Fax:03-3405-1854

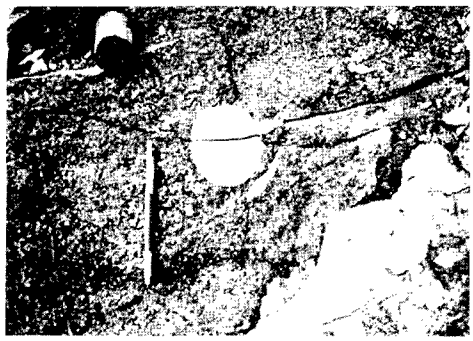

Photo 2 Crack occurrence after grouting treatment

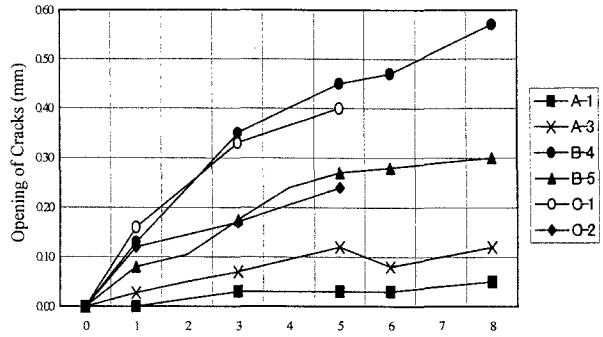

Fig.1 Results of the opening of cracks

3.Tests and Analysis of Rock Materials

The adverse physical conditions caused the Contractor to incur much extra cost and time loss. The Contractor should verify that the adverse physical conditions were not foreseen by an experienced contractor, otherwise any extra cost and time loss suffered due to those adverse conditions could not be reimbursed. Thus, the Contractor executed tests and analysis to examine the geological properties for the verification.

Samples of rock materials were examined by means of mineral analysis and chemical analysis in Japan so as to define the minerals contained in rock and to examine causes of the aforesaid geological phenomena.

① Polarization-Microscope Test and Analysis of Rock Minerals

As a result of the examination, minerals that constituted Diabase rock were mainly plagioclase, olivine and clinopyroxene. Zeolite, Chlorite and Smectite, which were minerals altered from the said minerals were also observed. The minerals including olivine were holocrystallic and idiomorphic texture.

② X-ray Diffraction Analysis of Mineral Material

X-ray diffraction analysis was executed to examine clay minerals that were kinds of altered minerals contained in Igneous Rock. Some kinds of clay minerals had properties, which generally caused swelling by reacting to water and eventually leaded to a lowering in the rock strength. "Smectite" and "Saponite" were observed by the polarization microscope, which were typical clay minerals in question.

4. Study and Verification based on Examination and Analysis

Most of Diabase contained a peculiar clay mineral called Smectite that had swelling properties and high cation-exchange capacities. Smectite had the layered crystal structure that swelled when it absorbed H_2O in the space between each layer (refer to **Fig.2**). This swelling weakened the cohesion between each crystal resulting in a lowering of the strength of rocks. It was explainable that most of the peculiar geological phenomena could be attributed to Smectite and the Contractor could not anticipate them reasonably.

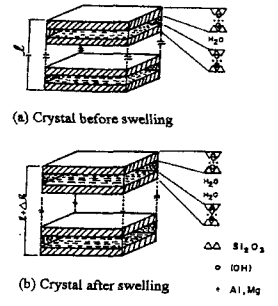

Fig.2 Change of crystal structure by swelling (Schematic figure)

5. Conclusion

Unforeseeable geological conditions are frequently experienced by contractors working in the overseas projects because geological information provided in advance is usually limited for precise cost estimation and construction planning. Contractors should anticipate any risk related to adverse geological conditions and prepare counter-measures to overcome such risks. This report provides technical measures to reasonably verify the contractor's entitlement in terms of reimbursement of damages caused by adverse physical conditions.