Safety Verification of Sabo Dams Against Large Scale Debris Flow

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INTRODUCTION

There have been recent damaged examples of Sabo dams against large scale debris flow. This was caused due to large rocks carried in the debris flow triggered by torrential rainfall of abnormal weather. This paper presents a safety verification method of Sabo dams against large scale debris flow (hereafter, called as load level 2 against load level 1 which is the usual design load). First, the load level 2 should be considered from the topographical point view at the dam construction point. Then, the load level 2 is determined by examining the field survey or past large debris flow disasters. Second, the safety verification method of Sabo dams is proposed against the load level 2. Finally, numerical examples of concrete and steel open type Sabo dams are illustrated against large rock impact of load level 2.

NECESSITY AND DEFINITION OF LOAD LEVEL 2: Large Scale Debris Flow

In order to verify the structural safety of Sabo dams against large scale debris flow (load level 2), it is needed to consider and define ‘the load level 2’.

Necessity of load level 2

If one of the following conditions is expected to happen, then the load level 2 should be considered from the viewpoint of the safety verification of a Sabo dam.

A. The topography such as steep slope and straight passage for debris flows.
B. The possibility of large scale sediment movement (large volume, flow rate, flow velocity and large rocks with the diameter of more than 3m).
C. The possibility of deep-seated landslide.

Definition of load level 2

The loads on a Sabo dam are considered as self-weight load, hydrostatic pressure, filled soil pressure, debris flow fluid force, earthquake load, rock impact load, woody debris, and uplift pressure. Herein, the loads onto the dams are classified as load levels 1 and 2 as follows.

(1) Load level 1 is defined as the current design load, with a return period of about 100 years.
(2) Load level 2 is defined as the large scaled load considering conditions A-C described above, with a return period of 200-500 years.

Determination method of load level 2

a. By examining the possibility of the deep-seated landslide.
b. By investigating the relationship between annual exceedance probability of rain and large scale sediment movement (volume, flow rate, flow velocity, huge rock diameter).
c. By examining the field survey reports of the past large scale debris flow disasters (i.e., fluid force, impact force, and flow velocity, and acting position.)
d. By developing the load estimate method using DEM or DEM-MPS simulation.
e. By using the extreme stability condition for the exsisting Sabo dam expediently.

SAFETY VERIFICATION OF SABO DAM

External stability against load level 2

Stability analysis for a steel open dam against load level 2 is simplified into a two-dimensional rigid body analysis of a cross section of the structure.

(1) Overturn condition: The safety ratio between resistant moment and overturn moment should be larger than 1.0.

(2) Sliding condition: The safety ratio between the shearing force capacity and the acting shearing force at the dam base should be larger than 1.0.

(3) Bearing capacity condition: The safety ratio between the subgrade reaction capacity and the acting subgrade reaction onto the dam base should be larger than 1.0.

Internal structural safety against load level 2

(1) Serviceability limit state (SLS) corresponds to the limit of damage not affecting the capturing function of a dam. That is, actual behavior $\leq$ allowable behavior.

(2) Restorability limit state (RLS) corresponds to moderate damage. The RLS is defined as the maximum damage level which allows planned maintenance and repair methods to be used.

(3) Ultimate limit state (ULS) corresponds to severe damage, for instance, structural failure or excessive deformation of the component or the structure under debris flow hazards.

The basic concept of limit states is shown in **Fig.1**.

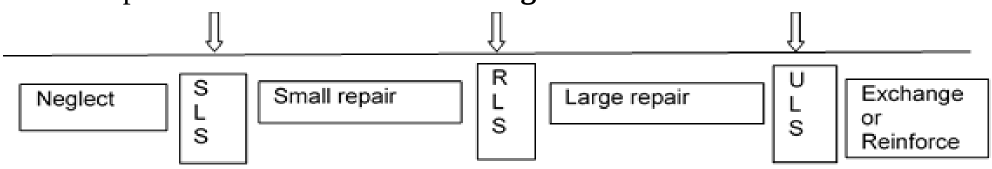

Fig.1 Basic concept of limit states

EXAMPLES OF DYNAMIC FEM ANALYSIS

Fig. 2 and **3** show the final damages of concrete and steel open dams against rock impact with diameter of 3 m and velocity of 8.45m/s of load level 2, which were found by the field survey in Nashizawa disaster, Nagano, Japan, 2014.

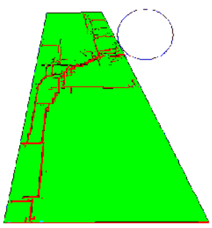

Fig.2 Damage of concrete dam

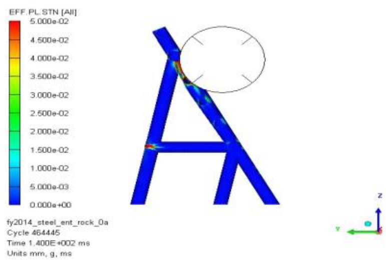

Fig.3 Damage of steel open dam

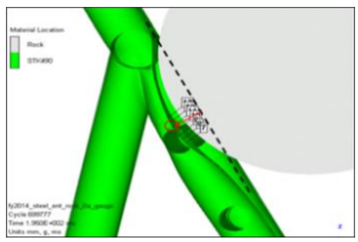

Fig.4 Local deformation profile at impact point against rock impact

Fig. 2 shows the damage of concrete dam in which the shearing failure and the tensile failure of the dam base have occurred over ULS. **Fig. 3** represents the damage of steel open dam in which the only local deformation exceeded ULS at the impact point as shown in **Fig.4**. The pipe component should be exchanged, but the whole dam was not so damaged.

CONCLUSIONS

The following conclusions were obtained from this study.

(1) The safety verification method of Sabo dams was proposed against large scale debris flow load (load level 2).

(2) The necessity, definition and determination method of load level 2 were proposed.

(3) As Shown in the numerical examples, damages to concrete and steel open Sabo dams were verified against the rock impact of the load level 2.

Keywords: Safety verification, Sabo dam, large rock impact, load level 2, dynamic FEM analysis