Paper:

Prediction of Floods Caused by Landslide Dam Collapse

Yoshifumi Satofuka*[1], Toshio Mori*[2], Takahisa Mizuyama*[3], Kiichiro Ogawa*[4], and Kousuke Yoshino*[5]

*[1]College of Science and Engineering, Department of Civil Engineering, Ritsumeikan University
Noji-higashi 1-1-1, Kusatsu-city, Shiga 525-8577, Japan
E-mail: satofuka@se.ritsumei.ac.jp
*[2]Sabo Frontier Foundation
SABO-Kaikan Annex 6F, 2-7-4, Hirakawacho, Chiyoda-ku, Tokyo 102-0093, Japan
*[3]Graduate School of Agriculture, Kyoto University
Oiwake-cho, Kitashirakawa, Sakyo-ku, Kyoto 606-8502, Japan
*[4]Asia Air Survey Co., Ltd.
Manpukuji 1-2-3, Asao-ku, Kawasaki-city, Kanagawa 214-0004, Japan
*[5]Asia Air Survey Co., Ltd. on loan to Incorporated Administrative Agency, Public Works Research Institute
Minamihara 1-6, Tukuba-city, Ibaraki 305-8516, Japan

[Received January 14, 2010; accepted April 30, 2010]

Landslide dam formation and deformation strongly affect water and sediment runoff. When a large-scale landslide dam collapses due to overflow erosion, peak flood discharge may exceed inflow discharge by several times. Such an abrupt flow discharge increase by a dam burst may cause serious damage downstream. We propose a one-dimensional model for river-bed variation and flood runoff consisting of a two-layer model for immature debris flow and a bank erosion model. We applied this model to the Nonoo landslide dam in Japan's Miyazaki Prefecture, formed by typhoon Nabi in September 2005, and China's Tangjiashan landslide dam formed in the Wenchuan earthquake in May 2008. The model reproduces the observed flood runoff processes in the two areas. Calculated results suggest that peak flood discharge diminishes when water accumulating behind the landslide dam is small, and excavating the landslide dam crown effectively reduces flood discharge.

Keywords: landslide dam, outburst, flood discharge prediction, two-layer model, river bed variation

1. Introduction

Landslide dams are formed when torrential rain or an earthquake causes a large-scale flank collapse damming the river channel. Potential downstream flooding makes it vital that risk information be communicated to affected areas. Measuring the landslide dam with an airborne laser and prompt numerical simulation based on measurement results enable the size of the flood to be predicted, and add to vital information.

In previous studies on landslide dam collapse and flooding, Takahashi et al. [1] classified sediment transportation and analyzed it by assigning flow resistance laws based on mode of sediment movement which greatly changes with land slope. Takahama et al. [2] proposed a two-layer model assuming an interface between an upside low concentration (water flow) layer and a downside high concentration (sediment movement) layer in analyzing immature debris flow with a governing equation for each layer. Based on these existing models, we developed a model to reproduce flood runoff accompanying landslide dam collapse [3, 4].

When a landslide dam collapses, flow is very high near the dam's crown, causing abrupt erosion. Once it starts overflowing from a specific point on the crown, the flowing concentrates to form a channel, and simultaneously with longitudinal erosion, causes transverse (side-bank) erosion that gradually widens the channel [1]. Takahashi et al. [1] used a two-dimensional river-bed variation simulation model considering transverse erosion of the landslide dam collapse successfully reproducing flood runoff having such landslide dam transformation. This assumes the shear force applied to the side bank to be half of the river-bed shear, and that the shear force causes side-bank erosion. This approach considers the relative elevation of the side-bank for the erosion rate, and assumes that the whole side bank regresses on an average. Takaoka [5] proposed a side-bank erosion rate equation on bed movement through experiments using straight channels, and concluded that the side-bank erosion rate equation was proportional to the flow velocity.

We use the above model first to numerically simulate the flood caused by the large-scale collapse of a landslide dam formed in the Mimikawa River watershed in Nonoo, Miyazaki, in September 2005 by typhoon Nabi (typhoon No. 0514). We then numerically simulate Tangjiashan landslide dam formed by the Wenchuan Earthquake in May 2008, and compare them to observed results.

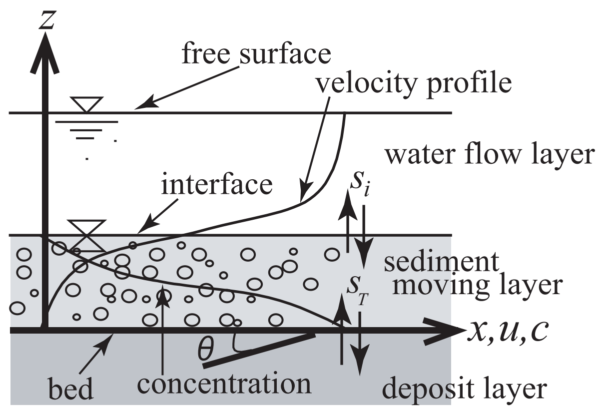


Fig. 1. Two-layer flow model.

2. Basic Calculation Model Equation

Figure 1 diagrams the two-layer model [2]. Takahama et al. [2] separate the water flow layer of water alone and the sediment movement layer containing a water/sediment flows to write the governing equation below with two-layer interface s_i flux. Subscripts w, s and t are for the water flow layer volume, sediment movement layer, and total of all layers.

The whole fluid layer continuity equation of is expressed as

$$\frac{\partial h_t}{\partial t}+\frac{1}{B}\frac{\partial B v_t h_t}{\partial x}=s_T+2ss_T\frac{h_t}{B} \quad \ldots\ldots \quad (1)$$

The continuity equation of sediment in the sediment movement layer is expressed as

$$\frac{\partial c_s h_s}{\partial t}+\frac{1}{B}\frac{\partial \gamma c_s B v h_s}{\partial x}=c_*\left(s_T+2ss_T\frac{h_t}{B}\right) \quad \ldots \quad (2)$$

The continuity equation of river bed is expressed as

$$\frac{\partial z_b}{\partial t}=-\frac{s_T}{\cos\theta} \quad \ldots\ldots\ldots\ldots \quad (3)$$

Given the relative side-bank elevation, change over time in river width is expressed as

$$\frac{\partial B}{\partial t}=2ss_T\frac{h_t}{H} \quad \ldots\ldots\ldots\ldots \quad (4)$$

To specify erosion rate of bed sediment in Eqs. (1), (2), and (3), we employ Egashira et al.'s formula [6] for two-layer flows:

$$s_T = \overline{v}\tan(\theta-\theta_e) \quad \ldots\ldots\ldots \quad (5)$$

$$\tan\theta_e = \frac{(\sigma-\rho_w)c}{(\sigma-\rho_w)c+\rho}\tan\phi_s \quad \ldots\ldots \quad (6)$$

The side bank erosion rate [5] is expressed as

$$ss_T=\frac{1}{\alpha}\overline{v} \quad \ldots\ldots\ldots\ldots \quad (7)$$

α is coefficient and $ss_T=0$ when $s_T\leq 0$.

The equations of motion of the water flow layer and the sediment movement layer are expressed as

$$\frac{\partial(\rho_w v_w h_w)}{\partial t}+\frac{1}{B}\frac{\partial(\rho_w\beta_w v_w^2 B h_w)}{\partial x}-\rho_w s_i u_I = \rho_w g h_w\sin\theta-\frac{1}{B}\frac{\partial P_w}{\partial x}-P_I\frac{\partial h_s}{\partial x}-\tau_w \quad \ldots \quad (8)$$

$$\frac{\partial(\gamma'\rho_s v_s h_s)}{\partial t}+\frac{1}{B}\frac{\partial(\rho_s\beta_s v_s^2 B h_s)}{\partial x}+\rho_s s_i u_I = \rho_s g h_s\sin\theta-\frac{1}{B}\frac{\partial P_s}{\partial x}+P_I\frac{\partial h_s}{\partial x}+\tau_w-\tau_b \quad (9)$$

ρ is average density, θ the riverbed slope, B the river width, h the fluid layer thickness, H the relative side-bank elevation, v the average flow velocity, g gravity acceleration, c the average concentration of all layers, c_s the average concentration of the sediment movement layer, $c_*(=0.6)$ deposit layer concentration, u_I the flow velocity in the x direction on the interface, and s_I the volume the water flow layer acquires per unit area and per unit of time through the interface. P_w is pressure applied to the water flow layer integrated from the interface to the free surface, P_s pressure applied to the sediment layer integrated from the river bed to the interface, P_I pressure on the interface, τ_w shear stress applied to the interface, τ_b shear stress on the river-bed surface, s_T gush volume (erosion rate) into the sediment layer through the river-bed surface, ss_T side-bank erosion rate, θ_e the equilibrium slope corresponding to the all-layer average concentration, ϕ_s the internal friction angle of sediment $(=35.0°)$ and z_b river-bed height. γ,γ',β_s and β_w are distribution correction factors resulting from the fact that the flow velocity, concentration, and density show the shape of distribution, all of which are 1.

We use the model by Egashira et al. [7] for each shear stress. The shear stress τ_w at the interface is expressed as

$$\tau_w = \rho_w f_w|v_w-u_I|(v_w-u_I) \quad \ldots\ldots \quad (10)$$

$$f_w = \left[\frac{1}{\kappa}\left\{\left(1+\frac{\eta_0}{h_w}\right)\ln\left(1+\frac{h_w}{\eta_0}\right)-1\right\}\right]^{-2} \quad (11)$$

$$\eta_0 = \sqrt{k_f}\left(\frac{1-c_s}{c_s}\right)^{1/3} d \quad \ldots\ldots\ldots \quad (12)$$

The shear stress τ_b for river-bed surface is expressed as

$$\tau_b = \tau_y+\rho_w f_s v_s|v_s| \quad \ldots\ldots\ldots \quad (13)$$

$$\tau_y = \left(\frac{c_s}{c_*}\right)^{1/5}(\sigma-\rho_w)c_s g h_s\cos\theta\tan\phi_s \quad . \quad (14)$$

When $G_{yk}\neq 0$:

$$f_s=\frac{225}{16}f(c_s)G_{yk}^4(W+G_{yk}) \times\left\{W^{5/2}-(W+G_{yk})^{3/2}\left(W-\frac{3}{2}G_{yk}\right)\right\}^{-2}\left(\frac{h_s}{d}\right)^{-2} \quad (15)$$

When $G_{yk}=0$:

$$f_s = 4f(c_s)\left(\frac{h_s}{d}\right)^{-2} \quad \ldots\ldots\ldots \quad (16)$$

Fig. 2. Nonoo landslide dam after collapse.

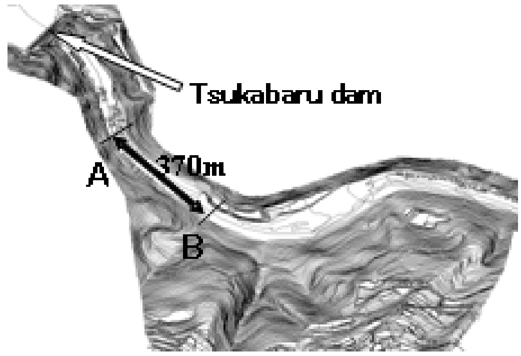


Fig. 3. Terrain map of Nonoo landslide dam.

$$f(c_s) = k_f \frac{(1-c_s)^{5/3}}{c_s^{2/3}} + k_g \frac{\sigma}{\rho_w}\left(1-e^2\right) c_s^{1/3} \quad (17)$$

$$\begin{aligned} G_{yk} &= \frac{\tau_{ext(z=z_b)} - \tau_{yk(z=z_b)}}{\rho_w g h_s} \\ &= \left\{ \left(\sigma/\rho_w - 1\right) c_s + 1 \right\} \sin\theta \\ &\quad - \left(\sigma/\rho_w - 1\right) c_s \cos\theta \left(\frac{c_s}{c_*}\right)^{1/5} \tan\phi_s \end{aligned} \quad (18)$$

$$W = \frac{\tau_w}{\rho_w g h_s} = \frac{f_w \left|v_w - u_I\right| \left(v_w - u_I\right)}{g h_s} \quad . \ (19)$$

σ is sediment density, $k_f = 0.25, k_g = 0.0828$, κ is Karman's constant, e is the coefficient of repulsion $(= 0.85)$, and d grain size. $\tau_{ext(z=z_b)}$ is shear stress as an external force on the river-bed surface and $\tau_{yk(z=z_b)}$ yield stress on the directly upper surface of the river bed. When G_{yk} is negative, the yield stress exceeds the external force in the sediment movement layer, In such condition, we expediently set the shear stress τ_w larger to avoid the excess. And we calculate u_I and f_s at the riverbed surface to fit the external force to the external force.

If the river-bed slope is small and the volume concentration on the fluid layer below 0.02, we use Manning friction factors as follows:

$$\tau_b = \frac{\rho g n^2 v |v|}{h^{1/3}} \quad (20)$$

n is the Manning roughness coefficient $(= 0.05)$.

3. Application to Nonoo Landslide Dam

3.1. Overview

Satofuka et al. [8] surveyed Nonoo landslide dam and computed flood flow, using the model illustrated in Chapter 2 and obtained interesting results. A part of the results is described here.

Figure 2 shows the Nonoo landslide dam, at the Mimikawa River watershed, in Miyazaki Prefecture. Torrential rains from typhoon Nabi in September 2005 caused the right-bank slope failure 370 m in the direction of flow between points A and B, downstream from the Tsukabaru Dam, as shown in **Fig. 3**, to form a landslide dam of 57 m high and 120 m wide, whose longitudinal profile is shown in **Fig. 4**.

Figure 5 diagrams the Nonoo landslide dam and the Tsukabaru Dam upstream. That prevented the Nonoo landslide dam inundation area from extending further upstream, reducing the size of the inundation. **Fig. 6** shows a plan view from the Tsukabaru Dam to the Yamasubaru Dam, a section of which forms a distinct valley with both sides of the river channel forming steep slopes.

Figure 7 shows the longitudinal river-bed profile and the longitudinal distribution of the river width. The x-axis is the distance measured downstream along the central axis of the valley originating at the Tsukabaru Dam, measured at 10 m intervals. **Fig. 8** shows the longitudinal river-bed profile and the longitudinal river-width distribution without the Tsukabaru Dam. We estimated the river bed shape in the upstream Tsukabaru Dam watershed by linearly connecting the river-bed level at the dam and that at the end of the reservoir, designating the river width as the width in filling period.

3.2. Numerical Simulation of Flood Runoff Caused by Nonoo Landslide Dam Collapse

3.2.1. Calculation Conditions

We made calculations in leapfrog scheme using the above basic equation, with the river channel as the rectangular cross section in all the sections.

Based on the grain size distribution measured at the red circle in **Fig. 2**, we use grain size d of the landslide dam of 40 cm at d_{60} (shown in **Fig. 9**). Coefficient α of Eq. (7) is $\alpha = 1000$. In the calculation, the initial river width on the landslide dam is set to be equal to the river width before the landslide dam formation.

We calculated on three cases listed in **Table 1**. In Case 1, we reproduced actual phenomena and calculated the section from the Tsukabaru Dam to the Yamasubaru Dam, shown in **Fig. 6**, with Tsukabaru Dam outflow, shown in **Fig. 10**, as an inflow condition from upstream. In Cases 2 and 3, we calculated the section from the end of the Tsuk-

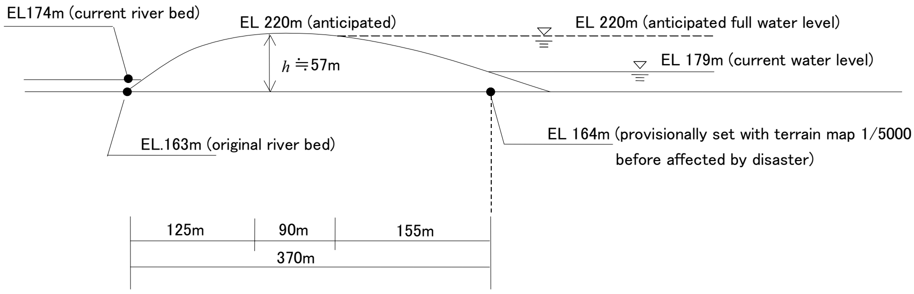


Fig. 4. Anticipated longitudinal profile of Nonoo landslide dam.

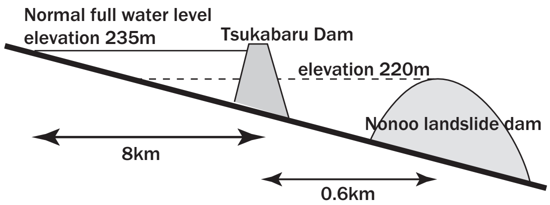


Fig. 5. Nonoo landslide dam and Tsukabaru Dam.

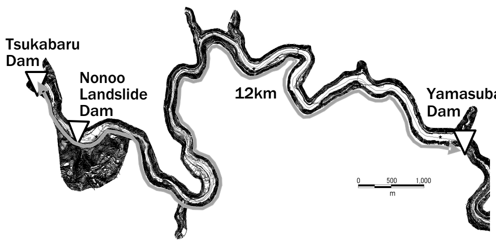


Fig. 6. Plan view of analysis target.

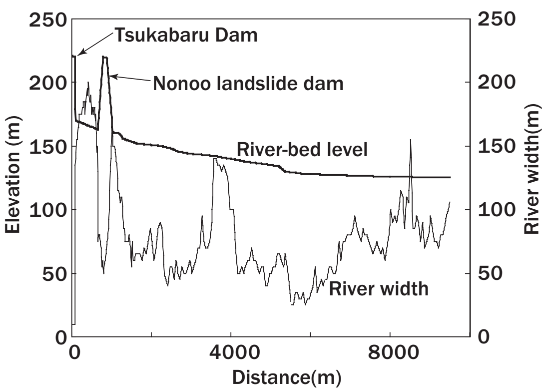


Fig. 7. Longitudinal river-bed profile and longitudinal distribution of river width from Tsukabaru Dam to Yamasubaru Dam.

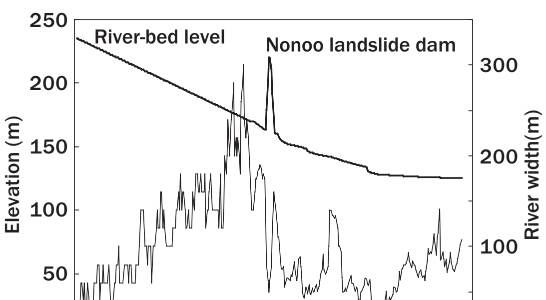


Fig. 8. Longitudinal river-bed profile and longitudinal distribution of river width assumed without Tsukabaru Dam.

Table 1. Calculation conditions.

	TsukabaruDam	Supply hydrograph
Case1	considered	Outflow data from the Tsukabaru dam
Case2	ignored	Outflow data from the Tsukabaru dam
Case3	ignored	Inflow data to the Tsukabaru reservoir

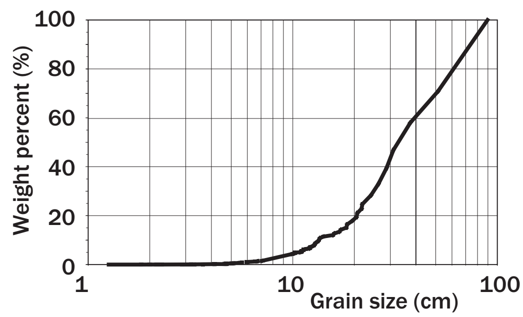


Fig. 9. Grain size distribution of sediment observed on site.

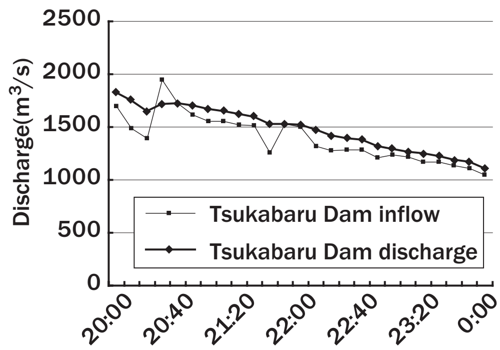


Fig. 10. Inflow and outflow of Tsukabaru Dam.

abaru Dam reservoir to the Yamasubaru Dam shown in **Fig. 6**, with Tsukabaru Dam outflow given as an inflow condition for Case 2, shown in **Fig. 10**, and with Tsukabaru Dam inflow for Case 3.

3.2.2. Calculated Results and Discussion

Change over time in the longitudinal Case 1 landslide-dam profile shown in **Fig. 11** indicates that erosion started from the downstream edge of dam's crown and the edge

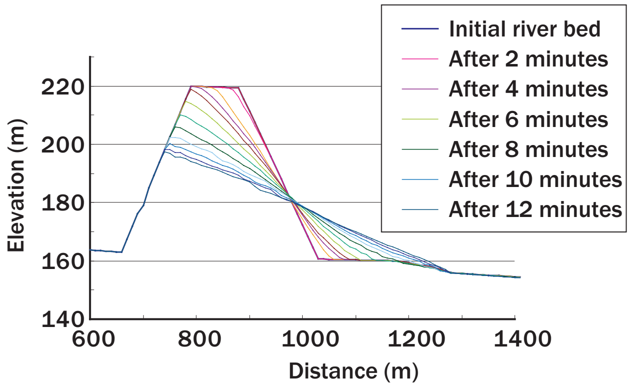


Fig. 11. Calculated results for Case 1 in Nonoo landslide dam erosion.

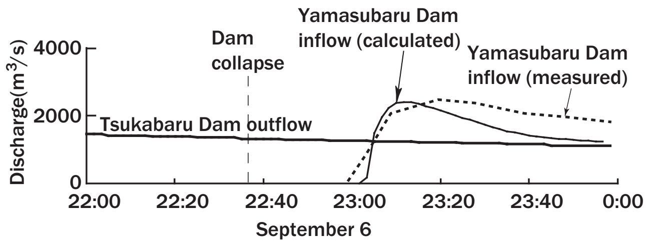


Fig. 12. Calculation versus Measurement in Yamasubaru Dam inflow.

gradually shifted upstream. As the crown's edge moved upstream, longitudinal erosion developed abruptly, as reproduced in the results for the channel experiment [1] related to landslide dam erosion and collapse.

Calculated and measured results for the Yamasubaru Dam supply hydrograph in Case 1 are compared in **Fig. 12**. For the measured value, we deduct Yanabarugawa River inflow, a tributary further downstream than the Tsukabaru Dam, to calculate discharge of the main Mimikawa River alone. This shows that although calculated discharge increases and decreases slightly faster, the overall flood hydrograph and peak discharge aresuccessfully reproduced.

Figure 13 shows calculation related to the flood hydrograph immediately below the landslide dam. Although Cases 2 and 3 use slightly different inflow conditions, calculated results are similar, so we compare Cases 1 and 2 in discussing the effects that the presence of the Tsukabaru Dam has on the flood hydrograph.

Peak discharge is 5500 m^3/s for Case 1 and 18,000 m^3/s for Case 2 – three times or more. In Case 1, the landslide dam began collapsing one hour and ten minutes after discharge was started, versus eight hours in Case 2. The difference was due to the Tsukabaru Dam having drastically reduced Nonoo landslide dam inundation.

Figure 14 shows the flood hydrograph of each case with the landslide dam collapse start as the origin. It took 20 minutes to flow 10 km from immediately below the landslide dam to the Yamasubaru Dam. Peak discharge is halved in Case 1. In Cases 2 and 3, peak discharge is reduced to just over 20% and discharge is 14,000 m^3/s in the Yamasubaru Dam inflow. Such flood runoff due to large-

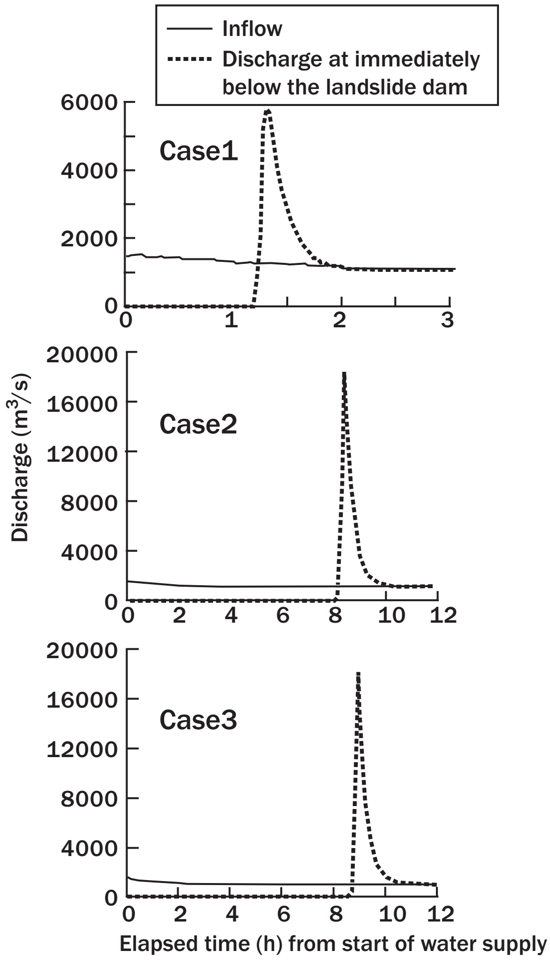


Fig. 13. Calculated flood hydrograph immediately below landslide dam.

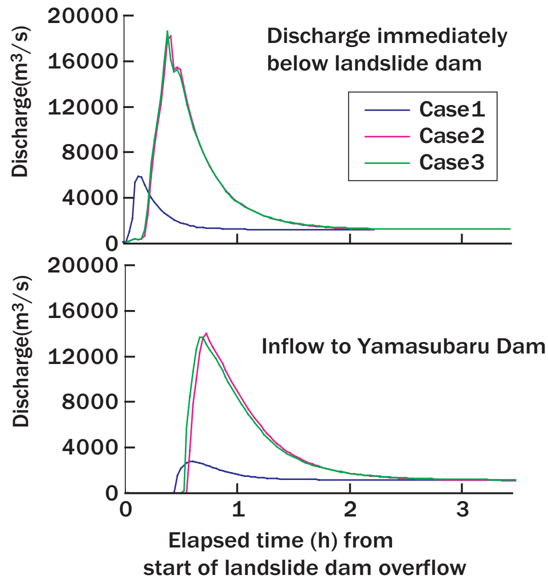


Fig. 14. Calculated flood hydrograph.

scale landslide-dam collapse is expected to cause major flooding downstream. The reason this did not occur may have been thanks to the presence of the Tsukabaru Dam.

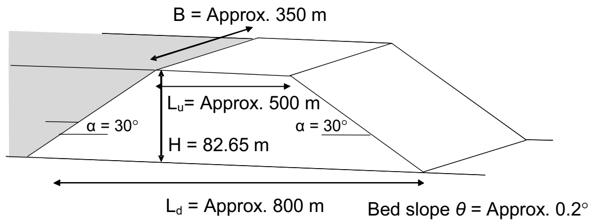


Fig. 15. Tangjiashan landslide dam used in calculation.

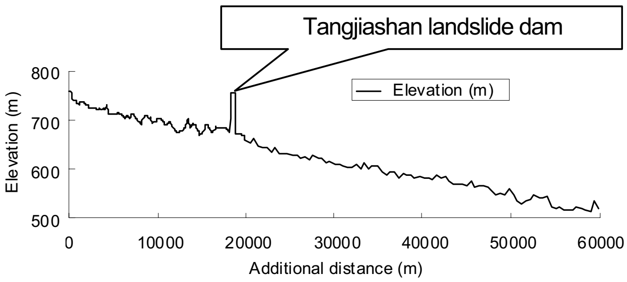


Fig. 16. Longitudinal river-bed profile.

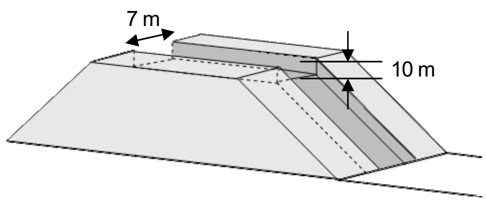


Fig. 17. Dam with channel excavated.

Table 2. Values used in calculation.

Water density	ρ_w	1.0 g/cm^3
Gravel density	ρ_s	2.65 g/cm^3
Average grain size	d	50 cm
Sediment layer density	C_*	0.6
Internal friction angle	ϕ_s	35°
Coefficient of restitution	e	0.85

4. Application to Tangjiashan Landslide Dam

4.1. Overview

Mori et al. [9] computed flood flow resulted from the Tangjiashan landslide dam deformation. A part of the results is described here.

The Tangjiashan landslide dam was formed in Beichuan County, Sichuan Province due to the China Wenchuan Earthquake in May 2008. The landslide dam is shaped as shown in **Fig. 15**, and the longitudinal river-bed profile is shown in **Fig. 16**. Chinese People's Liberation Army personnel excavated a channel 10 m deep and 7 m wide in the crown of the dam, as shown in **Fig. 17**, leading to a successful overflow at an early stage.

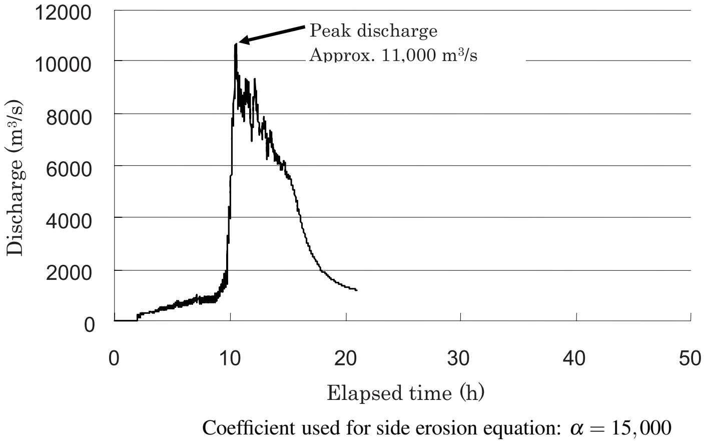


Fig. 18. Flood hydrograph at Beichuan City in Case 4, natural overflow.

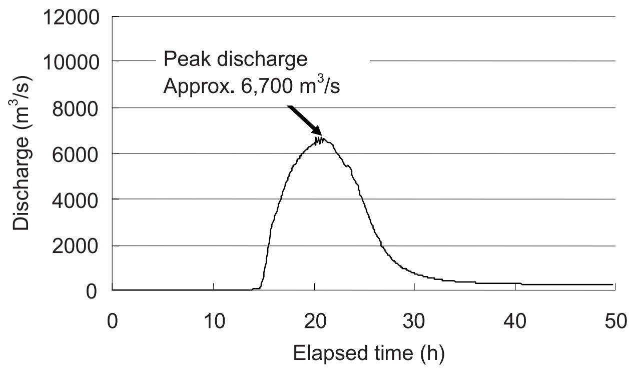


Fig. 19. Flood hydrograph at Beichuan City in Case 5 with channel excavated in crown.

4.2. Numerical Simulation on Tangjiashan Landslide-Dam Collapse and Flood Runoff

4.2.1. Calculation Conditions

Calculation conditions are shown in **Table 2**. Coefficient α of Eq. (7) is $\alpha = 15000$. Two-layer model calculations are made when channels were not excavated, Case 4, and when they were excavated, Case 5, as shown in **Fig. 17**.

The capacity of the Tangjiashan landslide dam is approximately 250 million m^3, and the catchment area is about 3,500 km^2. The inflow rate is assumed to be 1,000 m^3/s considering the huge catchment area.

In Case 4, the initial river width on the landslide dam is set to be equal to the river width before the landslide dam formation. In Case 5, the initial river width on the landslide dam is 7 m which is the width of excavated channel.

4.2.2. Calculated Results and Discussion

Figures 18 and **19** show Beichuan City flood hydrograph calculated in Cases 4 and 5. Peak discharges in Case 4 was 11,000 m$^{3/}$s and in Case 5 6,700 m^3/s. Calculated results in Case 5 are similar to 6,500 m^3/s in the

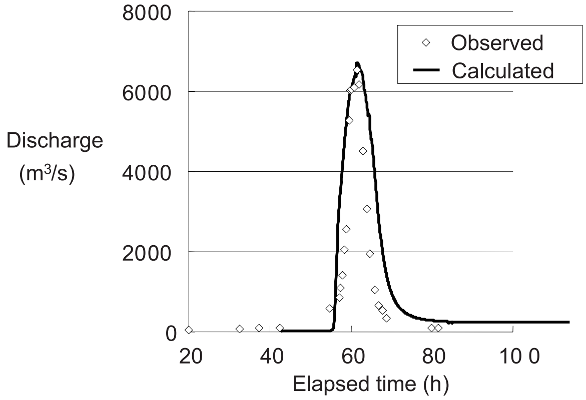


Fig. 20. Calculated versus observed flood discharge.

May 2008 issue of the IAHR Hydrolink newsletter. The value in the April 2009 issue is 6,420 m^3/s.

Figure 20 shows flood hydrograph observations from the Internet, overlapping with Case 5 results. The calculation seems to reproduce the actual flood, although the calculated flooding duration is slightly longer.

5. Conclusions

We have proposed a two-layer model of side-bank erosion to reproduce a flood caused by landslide dam collapse. Applying the model to the Nonoo landslide dam successfully reproduced the collapse process and flood runoff of the landslide dam. The presence of the Tsukabaru Dam upstream from the landslide dam reduced the inundation area, reducing the flood peak.

For the Tangjiashan landslide dam, an actual runoff hydrograph was successfully reproduced. Calculations show that the open-cut channels on the landslide dam crown made by the People's Liberation Army dramatically reduced peak flood discharge.

We need further study to obtain more detailed topographic data of landslide dams by Laser- Profiler etc. And we also need to improve the calculation model, especially side bank erosion model.

References:

[1] T. Takahashi and H. Nakagawa, "Flood and debris flow hydrograph due to collapse of a natural dam by overtopping," Proc. of Hydraulic Engineering, JSCE, Vol.37, pp. 699-704, 1993 (in Japanese with English abstract).

[2] J. Takahama, Y. Fujita, K. Hachiya, and K. Yoshino, "Application of two layer simulation model for unifying debris flow and sediment sheet flow and its improvement," Debris Flow Hazards Mitigation: Mechanics, Prediction, and Assessment, Rickenmann & Chen (Eds.), pp. 515-526, 2003.

[3] Y. Satofuka, Y. Yoshino, K. Ogawa, T. Mori, T. Mizuyama, and J. Takahama, "Reproduction of the flood that occurred by outburst of Takaiso-yama landslide dam," Journal of Japan Society of Erosion Control Engineering (JSECE), Vol.59, No.6, pp. 32-37, 2007 (in Japanese with English abstract).

[4] Y. Satofuka, Y. Yoshino, K. Ogawa, and T. Mizuyama, "Prediction of flood peak discharge at landslide dam outburst," Journal of Japan Society of Erosion Control Engineering (JSECE), Vol.59, No.6, pp. 55-59, 2007 (in Japanese with English abstract).

[5] H. Takaoka, "Study on erosion and sediment runoff by hyper concentrated flow," Doctoral thesis, Kyusyu University, pp. 7-23, 2006 (in Japanese).

[6] S. Egashira, N. Honda, and T. Itoh, "Experimental Study on the Entrainment of Bed Material into Debris Flow," Phys. Chem. Earth (C), Vol.26, No.9, pp. 645-650, 2001.

[7] S. Egashira, K. Miyamoto, and T. Itoh, "Constitutive equations of debris flow and their applicability," Proc., 1st Inter. Conf. on Debris-Flow Hazards Mitigation, New York, ASCE, pp. 340-349, 1997.

[8] Y. Satofuka, Y. Yoshino, T. Mizuyama, K. Ogawa, T. Uchikawa, and T. Mori, "Prediction of floods caused by landslide dam collapse," Annual Journal of Hydraulic Engineering, JSCE, Vol.51, pp. 901-906, 2007 (in Japanese with English abstract).

[9] T. Mori, T. Sakaguchi, Y. Sawa, T. Mizuyama, Y. Satofuka, K. Ogawa, N. Usuki, and K. Yoshino, "Method of estimation for flood discharges caused by overflow erosion of landslide dams and its application in as a countermeasure," Proc. of the INTERPRAEVENT Inter. Symposium on Disaster Mitigation of Debris Flows, Slope Failures and Landslides, 2010 (in printing).

Name:
Yoshifumi Satofuka

Affiliation:
Professor, Watershed Design Laboratory, Department of Civil Engineering, College of Science and Engineering, Ritsumeikan University

Address:
Noji-higashi 1-1-1, Kusatsu-city, Shiga 525-8577, Japan

Brief Career:
1989-2002 Disaster Prevention Research Institute, Kyoto University
2002- 2008 Graduate School of Agriculture, Kyoto University
2008- College of Science and Engineering, Ritsumeikan University

Selected Publications:
• "Sediment sorting in stony debris flow," Proc. of 4th International Conference on Debris-Flow Hazards Mitigation, CD-ROM, 2007.
• "Numerical Simulation on Debris Flow Control by a Grid Dam," Proc. of the 6th Japan-Taiwan Joint Seminar on Natural Hazard Mitigation, CD-ROM, 2006.
• "Variation of riverbed composed of sediment Mixture with Wide Size Distribution," Proc. 13th Congress of APD-IAHR, Singapore, Vol.1, pp. 234-239, 2002.
• "Prediction of Sedimentation Process in a Reservoir," Proc. 2nd IAHR Symposium on River, Coastal and Estuarine Morphodynamics, pp. 365-374, 2001.

Academic Societies & Scientific Organizations:
• Japan Society of Erosion Control Engineering (JSECE)
• Japan Society of Civil Engineering (JSCE)
• Japan Society for Natural Disaster Science (JSNDS)

Name:
Toshio Mori

Affiliation:
Director General, Sabo Frontier Foundation

Address:
SABO-Kaikan Annex 6F, 2-7-4, Hirakawacho, Chiyoda-ku, Tokyo 102-0093, Japan

Brief Career:
1971 Ministry of Construction
2002 Sabo Frontier Foundation

Academic Societies & Scientific Organizations:
• Japan society of Erosion Control Engineering (JSECE)

Name:
Takahisa Mizuyama

Affiliation:
Professor, Laboratory of Erosion Control, Division of Forest Science, Graduate School of Agriculture, Kyoto University

Address:
Oiwake-Cho, Kitashiraka, Sakyo-ku, Kyoto 606-8502, Japan

Brief Career:
1978-1990 Sabo Division, Public Works Research Institute, Ministry of Construction
1981-1982 Visiting researcher, Colorado State University
1990- Department of Agriculture, Kyoto University

Selected Publications:
• "Structural countermeasures for debris flow disasters," Int. J. of Erosion Control Eng. 1-2, pp. 38-43, 2008.
• "Measurement of bedload with the use of hydrophone in mountain torrents," IAHS Publ.283, pp. 222-227, 2003.
• "Sediment control with slit sabo dams," INTERPRAEVENT 2000, Villach Vol.1, pp. 251-258, 2000.

Academic Societies & Scientific Organizations:
• Japan Society of Erosion Control Engineering (JSECE)
• Japan Society for Civil Engineers (JSCE)
• International Association for Hydro-Environment Engineering and Research (IAHR)
• International Association of Hydrological Sciences (IAHS)

Name:
Kiichiro Ogawa

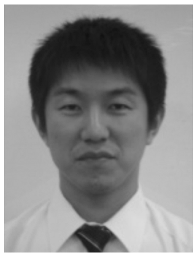
Affiliation:
Managing Officer and General Manager, Asia Air Survey Co., Ltd. Infrastructure System Development Center

Address:
1-2-3, Manpukuji, Asao-ku, Kawasaki-city, Kanagawa 214-0004, Japan

Brief Career:
1982 Joined Asia Air Survey Co.,Ltd.

Selected Publications:
• Yoshifumi Satofuka, Kousuke Yoshino, Kiichiro Ogawa, and Takahisa Mizuyama, "Prediction of flood peak discharge at landslide dam outburst," Journal of the Japan Society of Erosion Control Engineering, Vol.59, No.6, pp. 55-59, 2007.

Academic Societies & Scientific Organizations:
• Japan society of Erosion Control Engineering (JSECE)
• Japan society for Natural Disaster Science (JSNDS)



Name:
Kousuke Yoshino

Affiliation:
Asia Air Survey C., Ltd. on loan to Incorporated Administrative Agency, Public Works Research

Address:
Minamihara 1-6, Tukuba-city, Ibaraki 305-8516, Japan

Brief Career:
2004 Joined Asia Air Survey C., Ltd.
2009 On loan to Incorporated Administrative Agency, Public Works Research Institute

Selected Publications:
• Yoshifumi Satofuka, Kousuke Yoshino, Kiichiro Ogawa, and Takahisa Mizuyama, "Prediction of flood peak discharge at landslide dam outburst," Journal of the Japan Society of Erosion Control Engineering, Vol.59, No.6, pp. 55-59, 2007.

Academic Societies & Scientific Organizations:
• Japan society of Erosion Control Engineering (JSECE)