# Examination of Advanced Technical Measures for Landslide Dams Formed by Deep-seated Landslides

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## INTRODUCTION

Landslide dam induced serious damage due to flood triggered by landslide dam breach. Landslide dams can be classified into two in terms of the duration from the occurrence of landslide dam to the breach of landslide dam. Some landslide dam breached several hours later after the formation of landslide dam, while some other landslide dams remained several months to years. Here the first type landslide dam refers to "short-term collapse landslide dam" and the second type refers to "long-term remained landslide dam". To mitigate disaster due to short-term collapse landslide dam, structural countermeasures before forming landslide dams should be necessary. Here we introduce a case study about planning structural countermeasures to reduce damage due to short-term collapse landslide dam in the Jizouji River Basin of the Yoshino River System. This river is a class-A river with a basin area of approximately 93km$^2$, maximum flow channel length of 17.6km, and mean bed slope of 1/51.

## CLASSIFICATION OF LANDSLIDE DAM COLLAPSE TYPES

We assume that debris flows due to deep-seated rapid landslides moves down to the point where a gradient is 1/10 to form a landslide dam. According to this assumption and deep seated rapid landslide map, we set the possible locations of landslide dam formation.

To estimate volume of landslide dam, we used 1D debris flow numerical simulation model. We assume that all sediment deposits to form a landslide dam, and the shape of a landslide dam is the obelisk.

Then, we set the hydrograph which flow into landslide dam lake based on the historical flood data. In this study, the return period of used hydrograph is 100 years. Also, we assume that a landslide dam is formed at the peak of flood discharge. A landslide dam which collapses during a flood is classified as a “short-term collapse landslide dam”, and a landslide dam which does not collapse during a flood is classified as a “long-term remained landslide dam”. The major cases extracted from the collapse type classification result are provided in the **Tab.1**. The deep-seated rapid landslide at 13-7 and 13-6 in the **Tab.1**, whose landslide ponding capacity is greater than the flood capacity of 5.8 x 10$^5$m$^3$ after the peak, are classified as

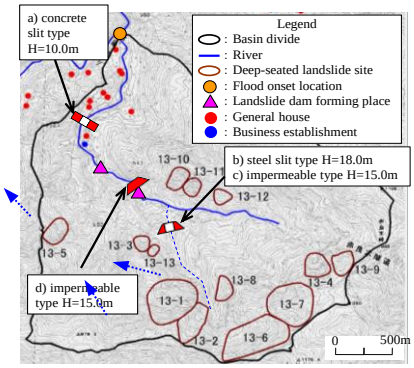


**Fig.1** Overview of the upstream area of the Jizouji River Basin

**Tab.1** Classification of major landslide dam collapse types

| No. | Dam height (m) | Ponding capacity(m$^3$) | Duration hours | Collapse type |
|---|---|---|---|---|
| 13-7 | 46.5 | 856,708 | - | Long-term remained landslide dam |
| 13-6 | 44.1 | 744,384 | - | Long-term remained landslide dam |
| 13-2 | 39.9 | 549,450 | 9.5 | Short-term collapse landslide dam |
| 13-11 | 16.5 | 53,996 | 0.5 | Short-term collapse landslide dam |

long-term remained landslide dam. Among short-term collapses landslide dam, the ponding capacity is the largest in 13-2, and smallest in 13-11.

**Tab.2** Plans on facilities measures and the effect on damage reduction

| | Without facilities | Plan to install a), b) and d) | Plan to install a), c) and d) |
|---|---|---|---|
| Landslide dam height(m) | 39.9 | 16.4 | 21.3 |
| Maximum discharge at the flood onset location($m^3/s$) | 1,583 | 183 | 200 |
| Flood area (ha) | 79.4 | 54.4 | 56.2 |
| Number of houses damaged | 55 | 25 | 31 |

## EXAMINATION OF COUNTERMEASURES AND EVALUATION OF EFFECTS

The strategy for structurally countermeasures against the deep-seated rapid landslide at 13-2, where the ponding capacity of landslide dam should be the largest among short-term collapses landslide dam, is shown below, and facility locations are shown in **Fig.1**.

I. Reducing discharge rate of debris flow and flood due to landslide dam breach:
  a) Dam type; concrete slit type Location; downstream of a landslide dam
II. Reducing the height of the landslide dam:
  b) Dam type; steel slit type Location; upstream of a possible landslide dam formation site
  c) Dam type; closed-type dam by full sand Location; upstream of a landslide dam
  d) Dam type; closed-type dam with deposited by sand Location; possible landslide dam formation site

We examined the plan to install either b) or c) as an additional type after installing a) and d). The effect of reduction in damage for both plans is shown in **Tab.2**. The landslide dam heights is reduced to approximately 40% by the plan to install a), b) and d), and to approximately 50% by the plan to install a), c) and d),and both the plans achieve the effect of reducing flood damage (flood area and number of houses damaged). In both plans, the peak discharge at the flood onset location is reduced to approximately 200$m^3/s$ from approximately 1,600$m^3/s$ in the case of the plan without facilities.

## CONCLUSIONS

1) It is possible to estimate damage considering a large basin downstream of the landslide dam, by composing flood discharge hydrographs which consist of outflow discharge of landslide dam collapse in addition to discharge from a basin downstream of the landslide dam.
2) By installing facilities upstream of landslide dams before forming landslide dams, it is possible to reduce landslide dam height since we decrease the amount of sediment transported from a deep-seated slope.
3) It is suggested that effective facilities include a proposal for sediment outflow control by installing both closed-type dams by full sand and steel slit dikes upstream of landslide dams, because we showed that facilities reduced landslide dam heights, the peak discharge and flood damage. If we install facilities downstream of deep-seated landslides, it is suggested that closed-type dams by full sand which form gentler slope and weaken direct impact by the debris flow can achieve more effectively than steel slit dikes.

We are going to examine effective facilities against deep-seated landslides; by reviewing the results in the case we apply the knowledge of this study to other river basins.

**Keywords**: landslide dam collapse types, short-term collapse landslide dam, measures to reduce damage