EFFECT OF MASONRY EMBANKMENT LOCATED ON MOUNTAIN SLOPE CALLED AS "IGA-BANE"

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ABSTRACT

Traditional counter measures for flood disaster mitigation are one of effective works for preserving river environment. A masonry embankment called "Iga-Bane" is discussed in this paper. This embankment built in 17th C still works for mitigating inundation damage of old village in Kameoka basin, Kyoto, Japan. The name has been derived from the name of the liege lord "Iga-no-kami" whose tenure was from 1648 to 1686. The objective of this paper is to investigate the effect of this embankment on disaster mitigation and safety evacuation by using a two dimensional shallow flow model with 5 m square mesh. Inundation depth and flow velocity were calculated in the four rainfall cases of 50mm/hr to 150mm/hr. It is found that the embankment changes flow direction of flash flood caused by heavy rainfall, and this prevents the village from inundation. It is found that the embankment mitigates inundation depth and flow velocity and that elderly female is able to evacuate safely during the flood.

Keywords: *Flood disaster, masonry embankment, mitigation of inundation, safe evacuation, calculation of inundation*

1. INTRODUCTION

Traditional counter-measures for flood disasters in Japan are divided into structural and non-structural measures. Structure, person and wisdom are the key words to understand the effects of each measure. One of the structural measures, masonry embankment, is discussed here. The first river work for disaster mitigation was done by the emperor Nintoku in the 4th century, and traditional river works have been constructed until the 19th century. Some works are still functioning in Kyoto and other districts of Japan. These are able to mitigate flood damages, but not to prevent them perfectly, however, the natural environment around rivers is preserved as a result. Their function has been investigated qualitatively, but not quantitatively. To study them quantitatively, it is necessary to study the function and availability by using numerical or hydraulic models. Inundation data by two dimensional shallow flow model is used in this paper to discuss flow condition and evacuation safety.

Kameoka Basin is on the west side of Kyoto and the area is about 40 km^2 as shown in Figure1. This basin was under the sea level about one million years ago, so alluvial plain was formed there. The Katsura River runs through the basin from north-west to south-east and connects to a narrow valley called "Hozu Gorge". This gorge works as a constriction during floods and the backwater extends over the basin. Then, the river water is flowing through open dykes to the surrounding flood plains and returns back to the river through another open dyke after flooding. The discontinuous bank of which upstream end is opened and connected to the downstream bank with a small angle of 10 to 30 degrees in this area. Effect of this open dyke was discussed in our previous work (Ishigaki et al., 2018).

2. MASONRY EMBANKMENT "IGA-BANE"

Masonry embankment "Iga-Bane" (Educational Board of Kameoka City, 2002) is located on the west-side mountain slope in this basin. The village named as Chitose-Kokubu is on the terrace caused by a slip on a fault and an ancient road passed through this village. There are old buildings such as the Atago shrine built in the 6th C and Kokubun-ji temple in the 8th C. The inhabitants of the day sometimes damaged by flash flood running from steep mountain, and they made a request of counter measures for mitigating the flood disasters. The lord made a masonry embankment on the mountain slope to change the flow direction and to protect the village on the skirt of mountain. “Bane” means the function of changing flow direction. the calculating flood area, including this village and back valley, is shown in Figure 1.

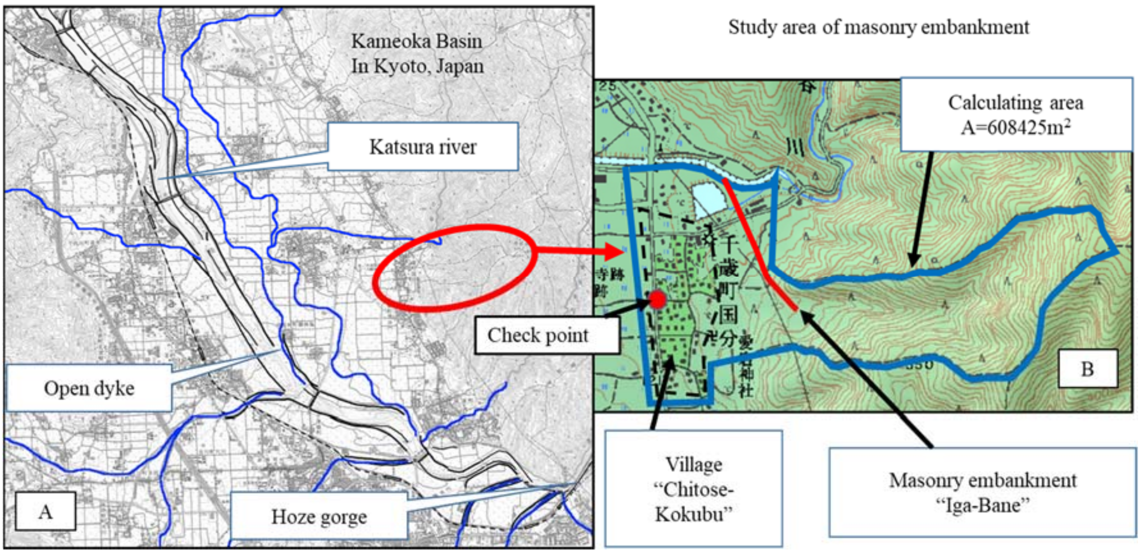

Figure 1. A. Kameoka Basin and its masonry embankment, B:Studied area of masonry embankment.

The topography of the study area is shown in Figure 2 and Figure 3 is longitudinal shape along the valley. It is found that the location of Chitose-Kokubu village is prone to flash flood running down the valley. This is the reason why the inhabitants wanted to build this masonry embankment to mitigate the flood damage. Iga-Bane works to change the direction of flash floods attacked the village. The embankment is covered with stones, as shown in Figure 4, and channel is formed with mountain slope and this embankment. In the channel, many hydraulic drops, as shown in Figure 4, are set to reduce the flow velocity of flash floods. As channel bottom is not covered with amount of sand, it is visible evidence that only rain-water runs through the channel during the flood.

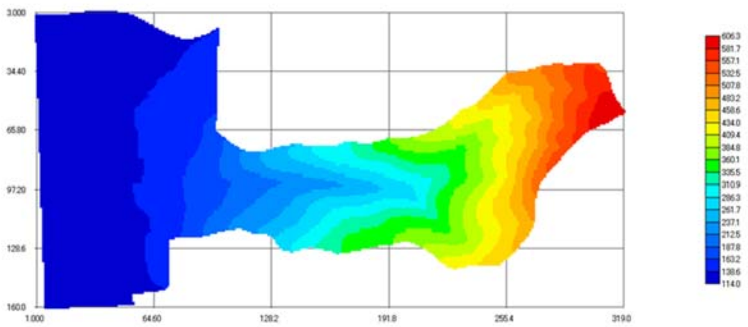

Figure 2. Topography of study area.

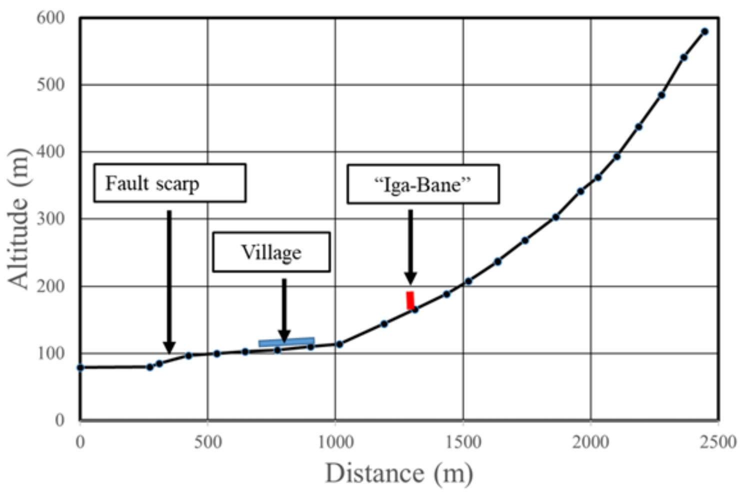

Figure 3. Valley slope, village and “Iga-Bane”.

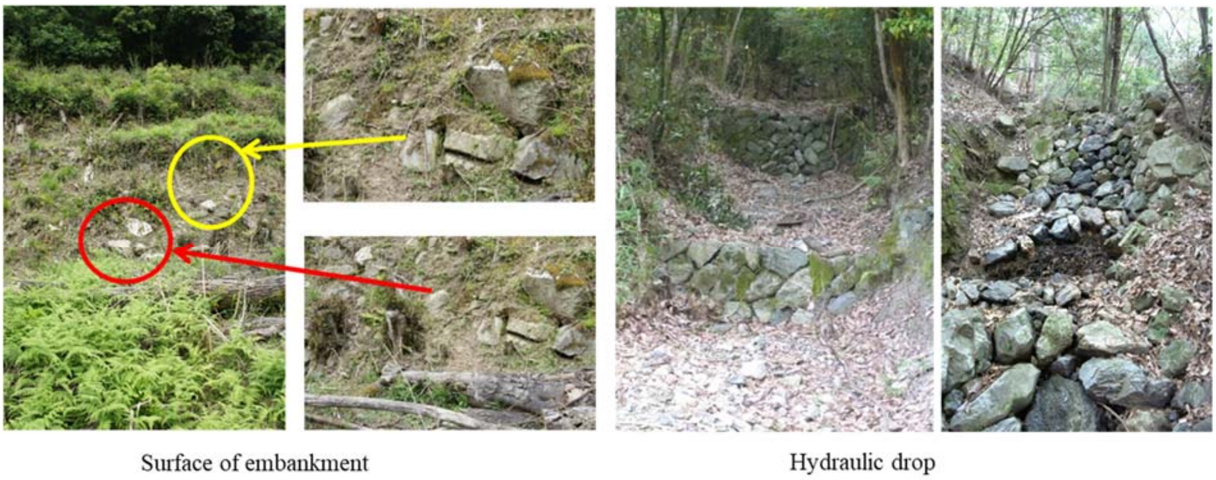

Figure 4. Surface of embankment and hydraulic drops

Field survey with Laser distance meter (Laser Technology Impulse 2000) was conducted to measure the height of embankment and channel width as shown in Figure 5. The length of this embankment is about 500m. One part is replaced with concrete channel to build a new walking pass. Figure 6 is the results of the field survey. The height of levee is 3 to 5 m, and the channel width is 1 to 1.5 m in which there are many masonry hydraulic drops.

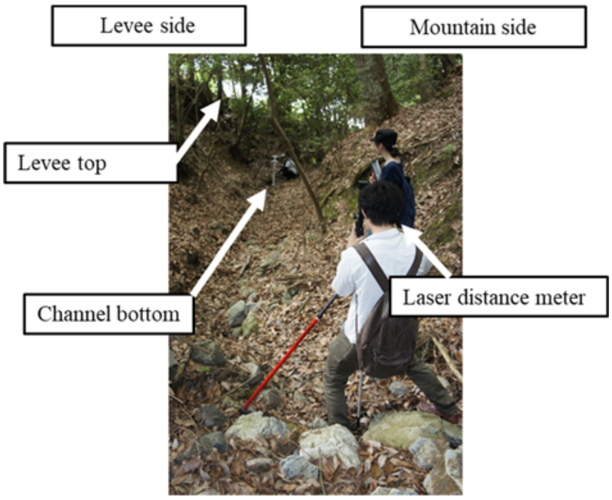

Figure 5. Field survey of Iga-Bane.

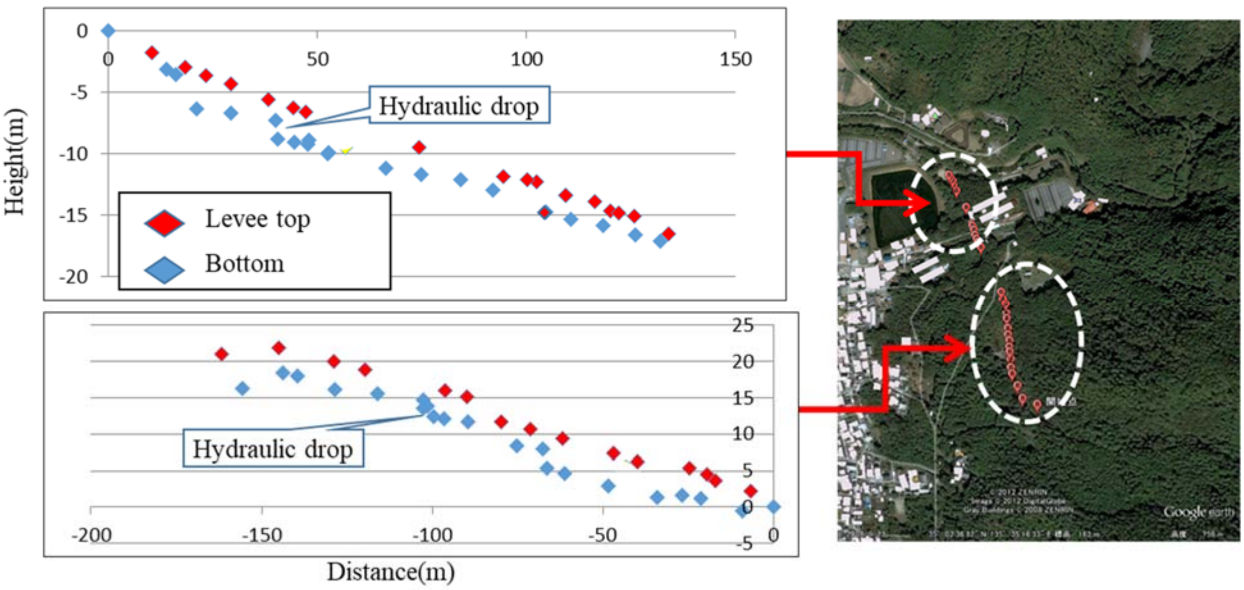

Figure 6. Field survey results of Iga-Bane.

3. FUNCTION OF IGA-BANE

3.1 Method

To investigate the effect of masonry embankment, a two dimensional shallow flow model with a 5m square mesh of 26026 grids was used to calculate inundation depth and velocity in the study area shown in Figure 1. Two numerical models with and without Iga-Bane in Figure 7 were used here. Manning's n was set at 0.04 for groves, 0.06 for mountain slope and 0.05 for village. Calculation conditions were in the cases for one-hour rainfall of 50mm, 80mm, 100mm and 150mm, and the calculation time was 7200 seconds.

Figure 7. Numerical model with and without "Iga-Bane".

3.2 Effect of Iga-Bane

Figure 8 shows the calculation results in the case of 150mm/hr. This figure shows that flood flow runs through the village in the case without Iga-Bane, and that flood flow runs along Iga-Bane in the case with the embankment. This means that Iga-Bane is effective in changing the direction of flash flood and mitigate the flood damage to the village. From the results in Figure 9, it is found that the inundation depth and flow velocity at the check point in Figure 1 is reduced. This also indicates that Iga-Bane is effective in mitigating inundation damage of flash flood.

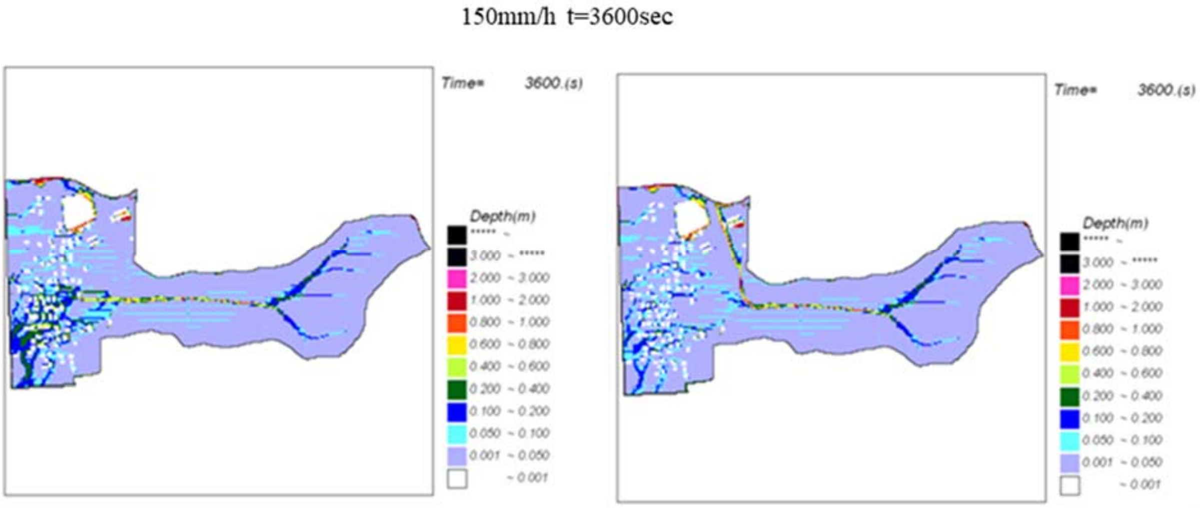

Figure 8. Inundation depth in with (left) and without (right) "Iga-Bane" cases.

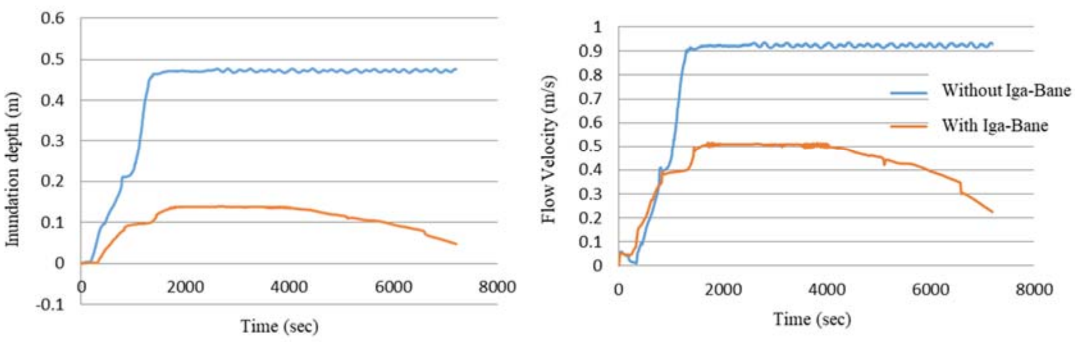

Figure 9. Inundation depth and flow velocity at the check point in with and without "Iga-Bane" cases.

By using these data, criteria for safe evacuation can be estimated. This criteria is proposed by authors based on the evacuation test by using a real size model of stairs and corridor, which is installed in the Ujigawa Hydraulics Laboratory of Kyoto University (Ishigaki et al., 2010; Asai et al., 2010). The specific force per unit width in Table 1 is calculated by the following equation,

$$M_0 = \frac{V^2}{gh} + \frac{h^2}{2} \tag{1}$$

where V is velocity, h water depth and g the gravity acceleration.

Table 1. Criteria of safe evacuation presented by the specific force per unit width, M_0 (m^3/m).

	Limit of safe evacuation	Difficult without any help
Male	0.125	0.250
Elderly male	0.100	0.200
Female	0.100	0.200
Elderly female	0.080	0.160

By using the criteria of safe evacuation, the safety of evacuation at the check point is able to plot in Figure 10. The criteria for elderly female is M_0=0.08 m^3/m. From the results, it is found that almost all people could evacuate in the with Iga-Bane case, and this means that Iga-Bane would be helpful for safe evacuation in this village.

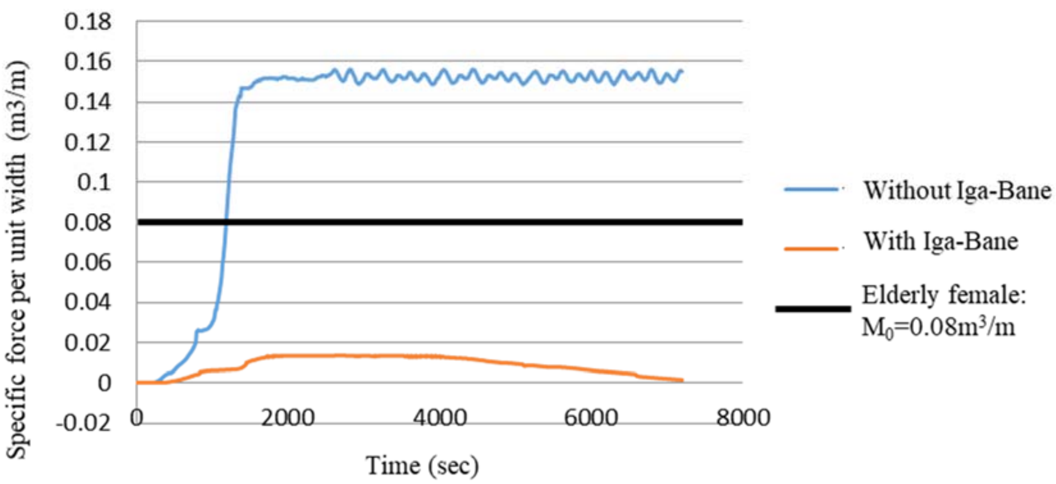

Figure 10. Criteria of safe evacuation at the check point.

4. CONCLUSIONS

Effect of the masonry embankment "Iga-Bane" in Kameoka, Kyoto was investigated quantitatively by using a numerical model. From the results, it is found that the embankment is very effective in mitigating the damage of inundation. In the village protected by Iga-Bane, inhabitants can evacuate safely because the embankment works as a training channel and changes the direction of flood flow. This function is the major effect of the masonry embankment "Iga-Bane".

Traditional counter measures consist of green infrastructure and preserve the natural environment around them, so these measures could be used if they were investigated quantitatively. These measures have the possibility that they could be one of methods for ecosystem-based disaster risks reduction.

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REFERENCES

Asai, Y., Ishigaki, T., Baba, Y. and Toda, K. (2010). Safety analysis of evacuation routes considering elderly persons during underground flooding, Journal of Hydroscience and Hydraulic Engineering, JSCE, Vol.28, No.2, 15-21.

Education Board of Kameoka City (2002). Iga-Bane.

Ishigaki, T., Kawanaka, R., Hayashi, M. (2018). Effect of Open Dyke for Flood Disaster Mitigation in Kyoto, Proceeding of the 21th IAHR-APD Congress 2018, Yogyagarta, Indonesia, Vol.2, pp.1153-1159.

Ishigaki, T., Asai, Y., Nakahata, Y., Shimada, H., Baba, Y. and Toda, K. (2010). Evacuation of aged persons from inundated underground space, Water Science & Technology, 62.8, 1807-1812, IWA Publishing.