A SUITABLE RISK INDEX FOR EVALUATING BRIDGE DAMAGE IN THE MISASA RIVER CAUSED BY THE 2018 WESTERN JAPAN FLOODS

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ABSTRACT

The 2018 Western Heavy Rainfall caused huge floods across a wide area of western Japan on July 5–8, 2018, followed by significant damage to people and their homes. In the Misasa River, which is a branch of the Oota River, Hiroshima prefecture, Japan, 22 out of 94 bridges were damaged by the flooding. The purpose of this study is to examine the characteristics of the bridge failures in the Misasa River. We also propose an index suitable for bridge damage assessment under heavy rainfall based on the longitudinal distribution of bridge damage in the Misasa River. From the results, it is statistically clear that the characteristics of the bridge damage can be related to the non-dimensional cross-sectional area (= cross-sectional area / upstream catchment area) and girder thickness / hydraulic radius. An evaluation procedure for bridge damage risk using these indicators is also examined on a trial basis.

Keywords: bridge damage, floods, risk assessment, local scour, 2018 Western Japan Floods

1. INTRODUCTION

Heavy rains can cause huge floods with serious damage to a range of infrastructure, including bridges. Floods are, worldwide, one of main causes of bridge damage (Wardhana and Hadipriono, 2003). An extremely heavy rainfall occurred over wide areas of Japan from June 28 to July 8, 2018, which was called the 2018 Western Japan Floods and caused a major flood disaster for humans, houses, and infrastructure (e.g., Nihei et al., 2019). For example, in the Misasa River, which is a branch of the Oota River, Hiroshima prefecture, Japan, 22 out of 94 bridges were damaged by the 2018 Western Heavy Rainfall (Yamamura and Nihei, 2019). In general, field surveys of bridge damage have mainly focused on individual damage factors, such as pier scour and the capture of driftwood. In contrast, our research group conducted surveys of bridge failure on all 94 bridges on the Misasa River caused by the 2018 Western Heavy Rainfall and determined the longitudinal distribution characteristics of the bridge damage. Using field data collected by Yamamura and Nihei (2019), this study proposes an index suitable for the evaluation of bridge damage caused by floods. For this, we use the longitudinal distribution of bridge damage in the Misasa River. The various dimensional and dimensionless indices related to hydraulic and structural factors are statistically examined to evaluate bridge damage. This study is a part of Inoue et al. (2019).

2. METHOD

2.1 Study site

The Misasa River, chosen as the study site, has a basin area of 274 km^2 and a channel length of 42 km. Figure 1 shows the basin of the Misasa River. The main tributaries of the Misasa River are the Eido River, Seki River, and Ogawara River. Flood damage in the Misasa River occurred previously in 1965 and 1972, with no further major inundation damage until 2018.

2.2 Data collection

To assess bridge damage in the Misasa River, we conducted four field surveys on all 94 bridges on the river from August to December 2018. The bridge numbers were determined as shown in Figure 1. The bridge damage was classified into four types: failure, partial damage (local scour), partial damage (other), and no damage. *Failure* meant a collapse of bridge girders, and *partial damage* was subdivided into damage factors: local scour of piers and other. Figure 2 shows examples of each type of bridge damage. The map created of the bridge damage is shown in Figure 1. Among the 94 bridges, we found 11 failures, 6 partial damages (local scour), and 5 partial damages (other).

In the field survey, staff and an RTK-GNSS (Trimble R10 Model 2, Trimble Geospatial, Sunnyvale, USA) were used to measure the elevation of the bridges water marks due to the flood, and the height of the dike. The driftwood captured near the piers was evaluated by visual observation.

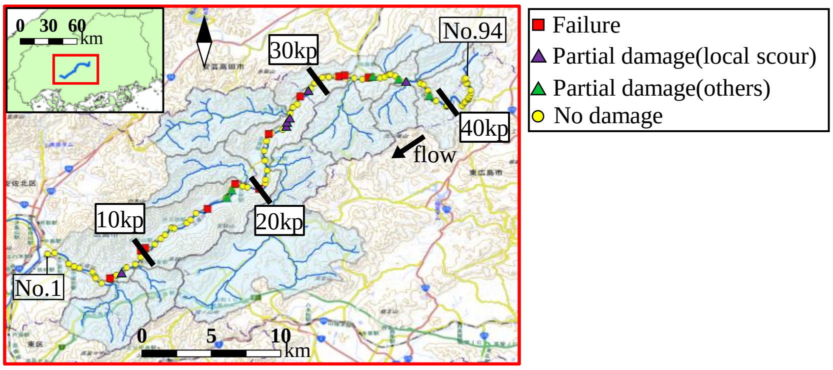

Figure 1. Study site and map of bridge damage caused the 2018 Western Heavy Rain.

Torikoe bridge **Ichimei bridge** **Yawata bridge**

Figure 2. A classification of bridge damages: (a) failure, (b) partial damage (local scour), and (c) partial damage (other).

3. RESULTS AND DISCUSSION

3.1 Longitudinal distribution of bridge damage and inundation area

Before comparing various risk indices for bridge damage, we examined the longitudinal distribution of the bridge damage, inundation area, and dike height along the whole Misasa River. The inundation area was concentrated in the middle reach of the Misasa River, and there was almost no flooding in the upstream area. Bridge damage was also concentrated in the middle reach, especially from 15 to 35 km from the conjunction of the Oota River. The failure of the bridges occurred in the inundation area.

3.2 Non-dimensional indices for the evaluation of bridge damage

Figure 3 shows the longitudinal distributions of the non-dimensional indices of various hydraulic and bridge factors. From various non-dimensional indices, we selected span / river width, hydraulic radius / river width, girder thickness / hydraulic radius, non-dimensional cross-sectional area, and inhibition rate of driftwood. Non-dimensional cross-sectional area is defined as the cross-sectional area divided by the catchment area at a target site. Inhibition rate of driftwood is the ratio of the projection area of driftwood captured on piers to the cross-sectional area. Examination of span / river width and hydraulic radius / river width failed to find a clear correlation between bridge damage and either index, as shown in Figure 3(a) and (b). Local minimum and maximum values of girder thickness / hydraulic radius appeared at the failures and partial damages, respectively, as shown in Figure 3(c). However, differences in the girder thickness / hydraulic radius between no damage and either failure or partial damage were not clear. Local minimum values of the non-dimensional cross-sectional area almost corresponded to the failure and partial damages, showing a good correlation between non-dimensional cross-sectional area and bridge damage, as shown in Figure 3(d). The non-dimensional cross-sectional area is the ratio of the cross-sectional area to the upstream catchment area, which is closely related to river discharge. This means that the non-dimensional cross-sectional area corresponds to discharge capacity. The catchment area and cross-sectional area ranged from 14 to 267 km^2 and from 69 to 958 m^2, respectively. It means that the non-dimensional cross-sectional area ranged from 1 to 5 [m^2 / km^2]. A smaller non-dimensional cross-sectional area indicates a smaller discharge capacity, which causes bridge damage. As shown in Figure 3(e), the variation pattern of the inhibition rate of driftwood was almost the same as that of girder thickness / hydraulic radius.

The above tendency was confirmed quantitatively by statistical analysis using a t-test. Based on the results, we selected the non-dimensional cross-sectional area and girder thickness / hydraulic radius together as the indices to evaluate bridge damage. It is noted that the non-dimensional cross-sectional area with the inhibition rate of driftwood would also be useful.

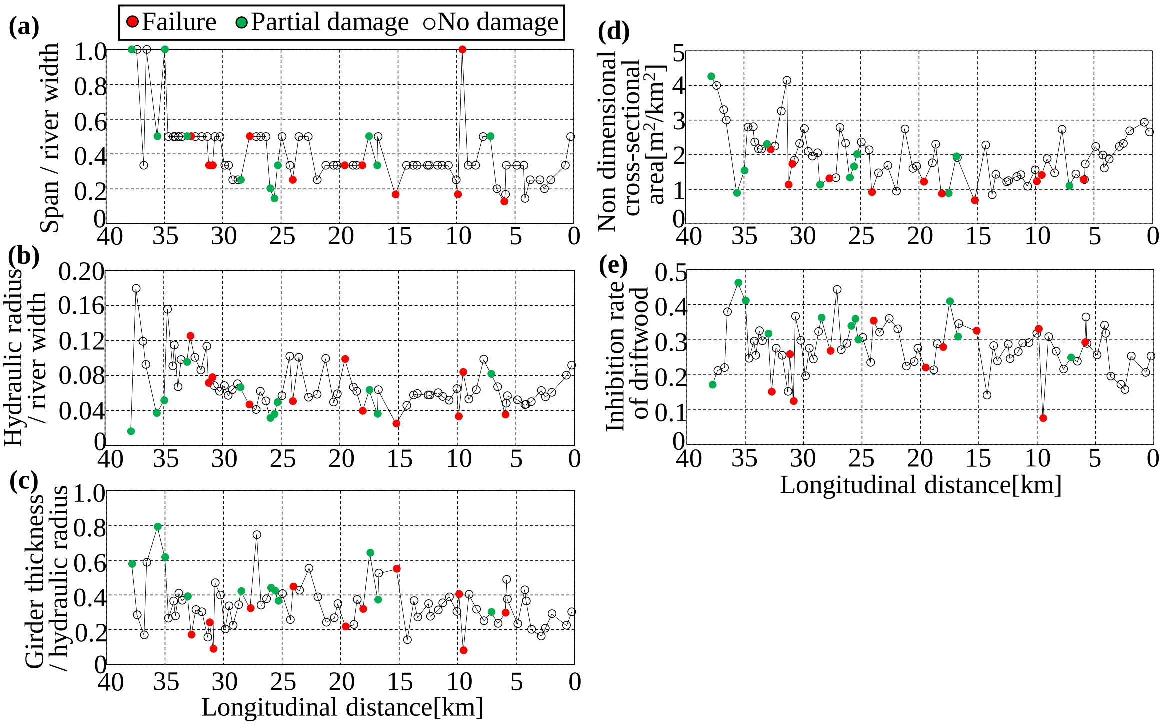

Figure 3. Longitudinal distribution of non-dimensional indices of bridge damage: **(a)** span / river width, **(b)** hydraulic radius / river width, **(c)** girder thickness / hydraulic radius, **(d)** non-dimensional cross-sectional area, and **(e)** inhibition rate of driftwood.

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