Analysis of the Impact on Traffic Functions of Scouring of Road Earthwork Structures and Slope Collapses, Etc. Due to Torrential Rain

(Research period: FY2021–)

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(Keywords) road earthwork structures, scouring, torrential rain, slope collapse, road function

1. Introduction

Road earthwork structures have been damaged due to disasters such as scouring and slope collapses, which have been caused by increasingly severe torrential rain, and there have been many events where the traffic function of roads has been lost.

This study analyzed the extent of the effects on traffic function (the state of traffic restrictions), looking at the manner of damage due to scouring (40 locations in FY2015–FY2020) and road slope collapse, etc. (112 locations in FY2019–FY2020: collapses of fill and cut slopes, sediment inflow, slope collapses) that were applied for and adopted as disaster recovery projects due to torrential rain, etc. on directly managed national roads.

2. Scouring of road earthwork structures

When we focus on the disaster factors in scouring disasters on roads adjacent to rivers, disasters caused by streambed scouring and full closures due to erosion from the revetment crown often occur. In outer curve sections (roads located on the outer shore side with respect to the curve in the center of the stream in a curve section of river), where streambed scouring occurs particularly easily, the proportion roads that are not passable to normal vehicles within one week after the disaster is high at about 70%. Because of this, we selected five representative locations of the above manners of damage (Hokkaido, Gifu, Hiroshima, Oita, Kumamoto), checked existing materials and conducted on-site investigations, while making use of topographic maps created with aerial laser surveying for contiguous sections including the damaged location (approx. 3 km), and compared damaged and undamaged locations in the section to extract conditions at high risk of damage.

(1) Damage due to streambed scouring

When grasping the state of streambed scouring, directly confirming scouring locations is not easy if the water flow is great, so we focused on the development of sandbars, which is one cause of streambed sinking, and analyzed changes to sandbars over time through past aerial photographs as a comparative easy method. As a result, the proportion of locations that suffered damage was roughly tripled if the location had a sandbar develop on the bank opposite the damaged location, compared to locations without a sandbar (fig. 1). Because of this, observing changes in sandbars over time appears to be effective as one method of inspecting to ameliorate the risk of damage.

(2) Disaster due to erosion from revetment crown

As a result of an analysis focusing on the disaster water level in the event of torrential rain (DHWL) and the revetment structures, structures with tamping above the revetment crown were damaged more easily than structures without it (fig. 2), and damage occurred in all locations when the water level in flood exceeded the revetment crown. In future, it is necessary to consider countermeasures incorporating conditions with a high likelihood of disaster, as there are many similar locations.

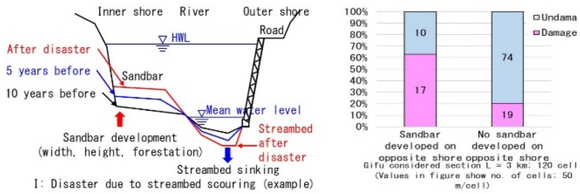

Fig. 1. Example of scouring damage due to sandbar development

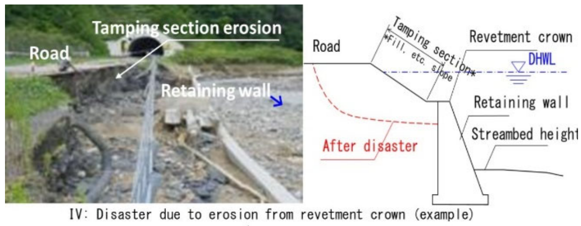

Fig. 2. Example of damage during water level rise due to torrential rain

3. Slope collapse, etc. on roads

The relationship between the manner of disaster and the level of its effect on traffic function shows that roads are likely to be entirely closed to traffic if sediment inflows from a stream, etc. or the slope collapses, and that most roads tend to be entirely closed to traffic when sediment inflow occurs in particular. Moreover, locations with catchment topography had a high proportion of full road closures for any manner of disaster. Because of this, we selected nine representative locations (sediment inflow: Iwate, Fukushima, Kanagawa, Kumamoto, Kagoshima; slope collapse: Kanagawa, Yamanashi, Oita, Kagoshima) for the above manners of disaster and took contiguous sections including the damaged location (approx. 1 km) as the sections for consideration. For these sections, we checked existing materials and conducted on-site investigations, while making use of topographic maps created with aerial laser surveying, and compared damaged and undamaged locations by making determinations based on whether sediment, etc. reached the road or not to extract conditions at high risk of damage.

(1) Disaster due to sediment inflow

We analyzed disasters due to sediment inflow, organizing them by the catchment area of the stream, distance, etc. In relation to the stream incline, we used the streambed incline for the manner of sediment movement (fig. 3) as a guide, and focused on an incline of 15° for the accumulation section, at which sediment begins to accumulate, established a rear incline, incline distance, and mean incline in stream as shown in red in figure 3, and organized the section distances between them.

As a result, when focusing on the relationship between the rear distance and the rear incline, sediment tended not to reach the road if the rear distance was 100 m or more (fig. 4). Moreover, the relationship between the stream catchment area and the mean incline in stream showed a trend where the damaged and undamaged locations can be classified at the point where the mean incline in stream is approximately 25° (fig. 5).

(2) Disaster due to slope collapse

We analyzed disasters due to slope collapse, organizing them by slope area, incline, catchment topography, etc. As a result, generally if the mean incline of the slope is less than 25° and the catchment area of the slope is less than 15,000 m², sediment did not reach the road in all locations. Conversely, generally if the mean incline of the slope is 20° or more and the catchment area of the slope is 15,000 m² or more, sediment reached the road in a high proportion of the locations (fig. 6). It should be noted that the learnings obtained from this study in relation to sediment inflow and slope collapse refer to trends in the extracted representative areas, and further consideration concerning their applicable in varied conditions on the ground appears necessary.

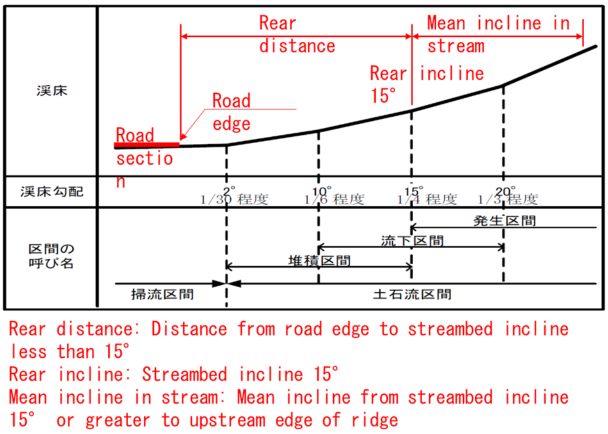

Fig. 3. Settings for matters for organizing sediment

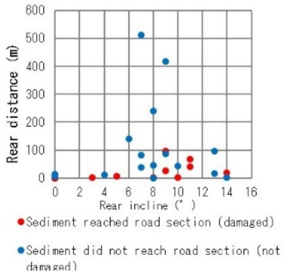

Fig. 4. Rear distance and rear incline

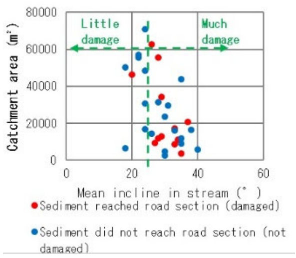

Fig. 5 Catchment area and mean incline in stream

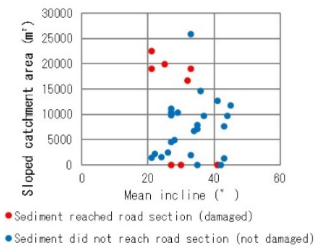

Fig. 6 Catchment area and mean incline in slope

4. Summary

As a result of an analysis of the effects on traffic function using the case of disasters on directly managed national roads due to recent torrential rain, etc., we obtained knowledge relating to conditions of high disaster risk, such as sections located on the outer curves of rivers and sections where the rear slope has an incline above a certain level and the catchment area is large. It should be noted that some of these analysis results are in the extracted representative sections, and we intend to continue collecting and analyzing disaster cases and reflecting the knowledge obtained in technical standards and other references.

☞See here for detailed information

"An Analysis of the Impact of Heavy Rain Damage to Road Earthwork Structures and Slopes on Road Traffic Functions", Civil Engineering Journal (2002), vol. 64, no. 8, pp. 30–33 [in Japanese]