For Reduction of Damage from Sediment Disaster

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1. Introduction

In the Kumamoto Earthquake last year, sediment disasters occurred at 190 sites, including the large-scale slope failure that blocked the national highway, JR line, etc. near the Great Aso Bridge, and seriously affected the local economy and society. In October of the same year, Mt. Aso erupted with plumes above 10,000 m altitude, but the volcanic ash did not reach the amount that causes debris flow or mud flow. On the other hand, in the 2014 Hiroshima Disaster, debris flows occurred simultaneously at different places in the urban foothill and killed more than 70 people. Thus, various types of sediment disasters occur in Japan in connection with heavy rain, snow melting, earthquake, volcanic activity, etc.
Under the Sediment Disaster Prevention Act put into force in 2001, prefectural governments are working for designation of "sediment disaster alert area" (yellow zone) and special alert area (red zone), and the total number of yellow zones are expected to reach about 650,000. This number can be recognized as a considerable number when compared with our familiar objects, such as traffic lights and convenience stores, which amount to about 200,000 and 55,000, respectively, across the country.
While there is a rising concern about intensification of local heavy rain due to climate change and occurrence of a large-scale earthquake such as Nankai Trough Earthquake or earthquake beneath the Tokyo metropolitan area, there is an increasing demand for effective measures to reduce the damage of various sediment disasters that could occur anywhere in the country.
This paper describes the trend of research and development, issues and future perspective in the sediment disaster field.

2. Mechanism identification of various disasters and countermeasure technologies

Various types of sediment disasters occur in Japan, such as debris flow, sediment flow, landslip, landslide, deep-seated landslide, landslide dam, debris flow after ash fall, and snowmelt-type volcanic mudflow. For each phenomenon, it is necessary to identify the mechanism of generation, run-off, deposition, etc. and study on structural / non-structural measures considering their characteristics.
For example, mechanism identification of run-off and deposition for debris flow has proceeded as the result of site survey, site observation with monitoring camera, water level gauge, etc., hydraulic model experiment, numerical analysis, etc., technical guidelines have been formulated and revised for planning and design of erosion control facilities, setting up the reference precipitation for warning and evacuation, land use regulation (red zone), method of determining the warning and evacuation area (yellow zone), etc. However, for the process of debris flow from generation to run-off, there are still issues to be solved, including rainfall and runoff characteristics (duration of rainfall, etc.) and peak discharge of debris flow. Also, further research and study are necessary on the planning and design of debris flow control facilities in the zero-order valley where valley terrain has not developed enough, measures for breakage at dam wing, etc. due to the collision of boulders etc. (resilient structure), effective structure of erosion control facilities in the gentle-slope section where sediment concentration is low.

Photo: Sediment disaster in the Kumamoto Earthquake

Since the frequency of larger-scale phenomenon is low, research and study are not proceeding sufficiently. For example, in the 2008 Iwate-Miyagi Inland Earthquake and the 2011 Typhoon Talas in the Kii Peninsula, etc., many deep-seated landslides, landslide dams, etc. occurred but it is difficult to pinpoint locations where such events are expected to occur in future. We, under the leadership of Public Works Research Institute ("PWRI"), have so far surveyed the risk of deep-seated landslide on the country-wide and mountain stream levels based on past disasters, geological structure, topographic quantity, etc. and implemented detailed surveys in high-risk areas, including micro-topographic analysis with LiDAR, geophysical exploration, drilling survey, and spring water survey. Further, PWRI prepared a manual of run-off / flood calculation method for debris flow resulting from deep-seated landslide. In the future, it is required to continue the research and study on reasonable countermeasures and methods that contribute to mitigation of damage from deep-seated landslide or landslide dam failure flood, and reflect them in specific projects.

3. Prioritized technical research and development

Prioritized technical research and development in NILIM are outlined as follows.

(1) Study for upgrading the forecast of sediment disaster using the real-time monitoring and observation data. Specifically, we grasp changes in sediment discharge, etc. using the sediment transport observation data from water gauges, pipe hydrophones, etc. and develop a technique to provide information with urgency. We also contribute to the provision of accurate information that is useful for stand-by of early action or determination of evacuation advisory by local government, through the use of phased array radar, development of the evaluation method of the occurrence potential of local heavy rain due to the formation of stationary linear precipitation zone, etc. We also develop a technique to search areas with high risk of deep-seated landslide, etc. using satellite SAR (Synthetic Aperture Radar) etc. immediately after large-scale earthquake, etc. Further, we are developing a new sensor for sediment disaster using AI (artificial intelligence), IoT (Internet of things), etc. jointly with the National Institute of Advanced Industrial Science and Technology, and aim to upgrade the technique for disaster risk assessment jointly with Osaka University, etc. including multi-stage evaluation based on rainfall characteristics, etc.

(2) We advance the study for establishment of the technique to estimate and address the damage of deep-seated landslide. Specifically, we are studying the frequency of deep-seated landslide, estimation of collapse scale, estimation of the scope of damage from debris flow caused by deep-seated landslide and from landslide dam failure flood, disaster reduction effect on erosion control facilities, etc. based on past disasters, numerical computation, etc. We also develop a technique to evaluate the probability of causing deep-seated landslide, etc. in combination of extraction of slight displacement on the slope with InSAR (interferometric SAR) technology, topographical analysis, ground survey, etc.

(3) Advance the study on slope failure risk assessment in case of a large-scale earthquake and dissemination of study findings. Specifically, we verify the landslide risk assessment based on assumed earthquake ground motions in the disaster prevention measures promotion area for Nankai Trough Earthquake (Kii Mountains) in cooperation with Kinki Regional Development Bureau, and disseminate the verification results. We also develop a method for effectively monitoring and observing the loosening of ground by earthquake ground motion with contract research, a technique to forecast collapse due to rainfall after earthquake, etc.

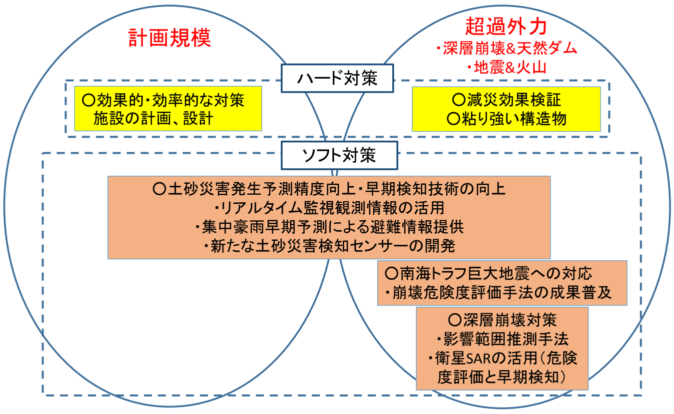

Figure: Study outline of the countermeasure against sediment disasters

4. Future perspective

Challenges for research and development from the medium- to long-term viewpoint are expected as follows, which are not limited to NILIM.

○ Establishment of a model for sediment run-off in the mountain stream channel considering the timeline of a flood and from several to several tens of years and development of sediment control technology by erosion control facilities.

○ Emergency survey in the event of volcanic eruption, deep-seated landslide, etc. using robots and development of techniques for emergency structural measures.

○ Development of construction technology for new erosion control facilities for productivity improvement (i-Construction, use of precast concrete, etc.)

○ Development of effective inspection diagnosis techniques and for strengthening / repair technologies in order to extend the life of erosion control facilities.

5. Conclusion

NILIM strives to grasp needs correctly and advance research activities through discussion with institutions concerned so that research findings are used for the practice in the central and local governments. Further, in order to promote innovation, we actively develop joint researches with other research institutions, universities, private enterprises, etc. and promote the utilization of new technologies including AI.