Relationship Between the Process of Large-scale Sediment Movement and Ground Vibration

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INTRODUCTION

It is known that a high sensitivity seismic network with some 20 km interval stations can detect small ground vibration caused by a deep-seated landslide. As such, vibration sensors are expected to be used as an effective means of detecting occurrence of a large-scale sediment movement. However, there is as yet no clear understanding of the relationship between ground vibration and the sediment movement process.

In this study, we compared ground vibration in the range of 1 − 7 Hz and low frequency ground vibration in the range of 0.01 − 0.1 Hz, which were caused by the Akadani large-scale landslide in Nara Prefecture, Japan on September 4, 2011 to establish the sediment movement process and the mechanism causing ground vibration. Video images recorded at the secondary collapse in 2014 were also examined.

GROUND VIBRATION AND SEDIMENT MOVEMENT PROCESS

Fig. 1 shows the vertical components of 1 – 7 Hz velocity and 0.01 – 0.1 Hz displacement waveforms, observed at Nokami station of F-net (F-net is a wideband seismic network established by National Research Institute for Earth Science and Disaster Resilience, Japan), 35.1 km away from the Akadani area. The frequency of vibration may represent the size of rocks which generate vibrations.

Tab. 1 shows our interpretation of the relationship between sediment movement and seismic data. In Stage 1, the upward displacement is inferred to be caused by the friction force of the descending collapsed sediment. In the following Stage 2, the displacement changed to the downward. This stage would show that the collapsed sediment collided with the riverbed and opposite bank. As there was no factor causing upward force after the collision in Stage 2, Stage 3 and 4 are inferred

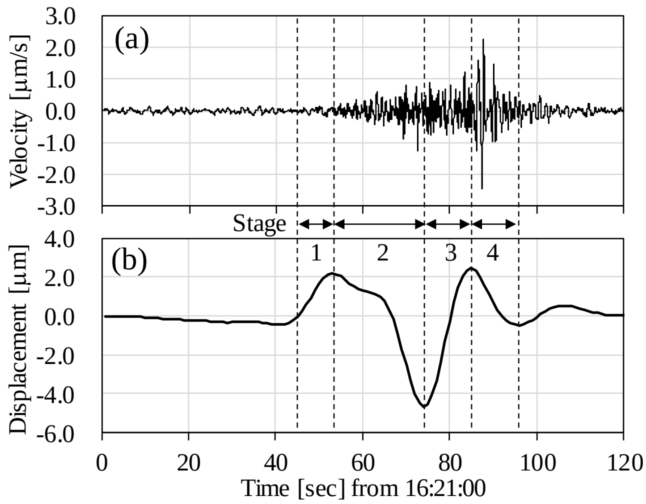

Fig. 1 Vertical components of (a) 1 – 7 Hz velocity and (b) 0.01 – 0.1 Hz displacement waveforms observed at 35.1 km away from the Akadani landslide in 2011.

to be a reaction to the former stage. On the contrary, the velocity of 1 – 7 Hz increases around Stage 3, and peaked in Stage 4. The peak of the waveform in 1 – 7 Hz delayed by some ten seconds from the peak time of low frequency of 0.01 – 0.1 Hz.

The geological structure of the landslide dam in the Akadani area shows a little fractured sliding rock mass layer at the bottom and fractured collapsed sediment above this layer. It is considered that transported rocks collided with the riverbed and the opposite bank at first, followed by the deposition of fractured sediment.

When it is assumed that the low frequency displacement waveform is the response to a large force acting on one direction and that the 1 – 7 Hz waveforms represent ground vibration by the collision of the fractured sediment, seismic records suggest that fractured sediment travelling a long distance from the top of the slope collided with the opposite bank after the settlement of the sliding rock mass.

Tab. 1 Relationship between low frequency or 1 – 7 Hz vibration data and sediment movement

Stage	Horizontal displacement	Vertical displacement	Time duration	1 – 7 Hz velocity	Interpretation of sediment movement
1	Towards↘ southeast	Upward	8 sec.	No vibration	Start of movement of the rock mass and reaching the opposite bank
2	Towards↖ northwest	Downward	21 sec.	Start of vibration	Start of collision of the rock mass with the opposite bank and completion
3	Towards↘ southwest	Upward	9 sec.	In the midst of increasing	Reaction to displacement (continued flowing down of fractured sediment)
4	Slight change	Downward	9 sec.	Peak	Settlement (flowing down of fractured sediment)

VIDEO IMAGE AND GROUND VIBRAITON

The secondary collapse in the Akadani area on August 10, 2014 was filmed in video. We compared the video images and vibration data at 10 km away from the collapse, considering the transmission time of seismic wave. No ground vibration of 1 – 7 Hz was observed during collapsed sediment flowing down the slope. The vibration started when the collapsed sediment reached the riverbed, and the amplitude peaked at the moment when sediment collided with the opposite bank. Although 1 – 7 Hz vibration was observed, 0.01 – 0.1 Hz vibration was not observed, probably because there was no sliding rock mass in this case.

CONCLUSION

Analysis of broadband seismic records and video images shows that vibrations lower than 0.1 Hz indicate the existence of sliding rock masses and vibrations higher than 1 Hz represent ground vibrations by the collision of the fractured sediment. This indicates the possibility of grasping the process of sediment movement by seismographs.

Keywords: Large-scale landslide, Sediment movement process, Seismic wave, Video image