Liquefaction and topographic change in Nishiaraya Area (in Ishikawa, Japan) caused by 2024 Noto Peninsula Earthquake

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Nishiaraya Area (in Uchinada Town, Ishikawa Pref., Japan) was severely damaged by the liquefaction phenomenon caused by the Noto Peninsula earthquake that occurred on January 1, 2024. Nishiaraya, the study area, is located near and on the southeast side of Uchinada Dunes (one of the biggest sand dunes in Japan, and about 60 m high at the maximum), and on the inland side there was Kahoku Lagoon that was once large and now mostly reclaimed. With respect to disaster, Nisharaya contrasted with towns developed on the top of the dunes that were scarcely damaged by the earthquake.
One of notable facts in Nishiaraya is that there were a lot of sand boils (sand volcanos) and ground fissures (cracks), even on paved areas. In unpaved areas, undisturbed cross sections of sand volcanos or ground fissures could be observed, and we found the case in which both occurred in an identical place. In that place, the sedimentary layer of the sand volcano was cut by the fissure, which suggests that the fissure was generated after the eruption of sand volcano, and the time-interval was more than duration for consolidation of belched liquefied sand, which was implied by the fact that the cross section of the sand volcano preserved its shape. The time lag means that the lateral (horizonal) movement of the land block causing cracks happened a certain period after the earthquake. In another place, however, a security camera footage showed that land block movement occurred at the same time as the earthquake. Another outstanding change after the earthquake in the study area was that pavements were turned up (ripped up) largely in a particular location. Such a phenomenon was concentrated along a road (Route 162) running on a boundary between the gentle-sloped residential area and the flat inland side.
We conducted topographic survey with UAV-LiDAR and obtained a topographic map with horizontal resolution of 1.5 cm and vertical error of less than 10 cm. We compared the map with a DEM (5 m mesh) provided by Geospatial Information Authority of Japan before the earthquake. The comparison revealed that most parts of the research area subsided 20 cm to 1 m. On the other hand, there was a raised zone, which corresponded to the area where upturned pavements were observed. It is considered that such phenomenon was caused by the land block that slid downslope and ran over the flat inland area at an inflection point of the slope. According to the aerial photo taken with the LiDAR measurement, there was a tendency in which the ground fissures occurred more often in higher places (more than 3 m a.s.l.) of the research area (about 0 to 6 m a.s.l.), while sand volcanos can be found also in lower places (below 3 m a.s.l.). The prominent contrast of damage between towns on the top of and at the foot of the dunes (the research area is the latter) can be presumably attributed to a groundwater level that is close to the ground surface in the research area. Shaking of the earthquake was of course the root cause of the disaster, but what increased the damage was groundwater that led to liquefaction of sand layer. The way of topographic change due to liquefaction was not uniform: vertical subsidence, lateral slide, both, and even uplift, depending on local and global topographic characteristics. Recovery of underground equipment such as water supply system in Nishiaraya is quite delayed. The information of the spatial distribution of topographic displacement obtained here will contribute to future disaster control.

Keywords: Liquefaction, Noto Peninsula Earthquake, Uchinada, UAV LiDAR

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