Reconnaissance Report on 2004 Niigata-ken Chuetsu Earthquake

1. Brief Summary of Earthquake

- Time of Occurrence: 17:56 pm. October 23, 2004
- Epicenter:Niigata-ken Chuetsu（N37.3°, E138.8°）
- Focal depth: about 20 km
- Magnitude: MJ 6.8
- Type of fault: thrust
- Number of sensible aftershocks: 2366 (until Oct.28)
- Japanese Seismic Intensity: 7 at Kawaguchi-cho
- Max. acc: 1008.3 cm2/s (Ojiya-shi, 3D composed)

2. Reconnaissance team of Geotechnical Laboratory, Chuo University

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3. Period of reconnaissance

First: Oct.25-26.
Second: Oct.31-Nov.2.

4. Comments:

4.1 Failure of natural slopes

The damaged area is known as landslide-prone area of green-tuff, with geological structure of active folding which covers active faults underneath. The mountain slopes there are composed of sedimentation soft rock of Neogene. More than a thousands of slope failures occurred due to main shocks and subsequent strong aftershocks. Typical height of slop failures were 30 m on average and rather steep around 30 degrees.

The slip surface was normally shallow, 1~2 m, sometimes leaving trees with deep roots. However, slope failures of other types were also observed. In Myoken, Ojiya-shi, huge rock slide occurred with deep slip surface, apparently, killing several people who were driving on the national road 17 along the Shinano River. The rock there is weathered mud stone with laminated sand stone, very soft, and can be broken by hands. The similar slip occurred a several kilometer upstream of the Shinano river. In a geomorphological view, the both site was attacked by meandering of the river. On the other hand, colluvial deposits in Nigorizawa in Nagaoka-shi or river terrace deposits in Shiodo in Ojiya-shi experienced slid with deep slip planes.

Some of the earthquake-induced slides are obviously influenced by previous landslide topographically.

In some sites, slid soil developed flow-type slide. For instance, in the Higashitakezawa pimary school building in Yamakoshi-mura, clear mud splash was noticed on the building outer wall and the mud debris rushed in the down-slope direction like liquefied soil.

A numerous number of ponds are located in Yamakoshi-mura from valleys to the higher levels of mountains. Some of the slope failures obviously involved ponds, which seems to provide water for soil liquefaction (actually sand boils were witnessed near the flow) and developed flow-type failure of the debris. Rainfall during three days before the quake was 120 mm, which may be another cause of larger flow distance. In addition to stairway rice pads peculiar in landslide area, the ponds tend to keep higher ground water level, presumably leading to higher occurrence of earthquake-induced slope failures.

More than 800 slope failures occurred in Yamakoshi-mura alone, the total volume of which ia reported to be around 60 million m^3. A number of slope failure debris stopped streams in valleys and made natural lakes. The largest lake inundated a small village and still increasing the reservoir level. This is a rare experience in the natural disaster history in Japan, and we should be well prepared for such damage

4.2 Road embankments

Numerous slope failures occurred in highways and normal roads in baking sections, interrupting road traffics for several days (for example Shiodono in Ojiya-shi). It involved some lifelines, mainly of information lines, buried at the edge of the embankments. The banking material was mostly sandy or clayey soils of low to medium plasticity presumably from crushed mud stone prevalent in this area. The height of damaged embankments was about 3 to 8 meters and in some places the failed debris developed flow-type failure at the toe spreading flatly on paddy fields.

Another peculiar failure mode of highway embankments was a lateral deformation of a total banking body resting on inclined ground. This lead to deformation of road culverts crossing embankments; opening the center joints which stopped traffics through them due to falling soil and uneven subsidence.

Uneven settlements concentrated between embankments and bridge abutments as often observed in other earthquakes, though they were treated immediately after the earthquake.

4.3 Earthdam

An Asagawara dam located near Tokamachi-shi was heavily damaged although no critical condition such as water leakage was experienced. The dam was a homogeneous type compacted earthdam with approximately 30 m height and 300m long at the crest. The slope inclination is about 1 to 2. About 5 open cracks appeared on the crest and the upstream side settled more than 0.5m. There seems no settlement on about a half of the crest width in the downstream side, indicating the dam deformed exclusively into upstream direction. The banking material was well compacted sandy loam.

4.4 Slope failure in newly developed residential land

Takamachi residential land of about 15 ha area is located on a hill in the suburb of Nagaoka-shi. It was constructed by cutting hill tops and banking the margin, presumably. The banking soil was protected by retaining walls about 4 m or higher all around the residential land. At three points the retaining wall failed and the banking soil slid down-slope considerably either during the main shock or during one of the string aftershocks. The failure occurred at the construction joint of the retaining wall and two wall spans between neighboring joints were pushed away. The soil there was mostly sandy but also included plastic clays originated from weathered mudstone. In other points, too, a lot of cracks and fissures were observed within 20-30 m from the retaining wall. At one place, a sand boil was witnessed, suggesting partial involvement of liquefaction.

4.5 Liquefaction damage

No severe liquefaction related damage occurred during the earthquake, though sand boils were witnessed in countless places near in damaged areas. Near Echigo-takiya JR station, liquefaction affected railway facilities, tilting electric poles or signal poles and waving the railway tracks. Many sand boils of clean fine sand appeared in that area. Lift-up of sewage manholes occurred many places because of the liquefaction of backfilling sands.

4.6 Foundation of Shin-kansen (Bullet train) viaduct

Foundation ground under the viaducts where the train derailed with the speed 210 km/h was surveyed in many sections of viaducts within about 1 km distance. The ground which is climbing up by several meters in the southern part consists of rice pad soil at the top and alluvial and Pleistocene sandy gravel underneath. The viaduct is supported by RC piles of 10 m length and the pile tip arrives at the sandy gravel. The SPT blow count there is reported as 10, which seems too low (personal opinion). It is reported that buried beams exist beneath the ground surface connecting neighboring viaduct columns. At some sections, there was a clear evidence of liquefaction under the viaduct presumably in loose backfilling sand. Mud splash made by push-up water from gaps between surrounding ground on the side of the columns were also clearly observed as well as ground subsidence in other sections. At almost all sections, open cracks could be seen above the buried beams, indicating large displacement of the viaduct foundation relative to foundation soils. By measuring the open cracks systematically, it may be possible to analyze the maximum displacement of the viaduct experienced for each section at least comparatively, providing valuable information for solving the cause of the derailment.

In contrast, there was only a slight evidence of liquefaction in natural ground next to the viaduct. Only a couple of small sand boils in paddy fields within 100 m from the viaduct. The maximum acceleration recorded at KiK-net site 5 km north from the site was about 800 cm/s^2 at the surface and 400 cm/s^2 at the base (G.L.-100 m). These observations indicate that the foundation ground did not liquefy extensively and only back-fill material liquefied or locally failed developing wide open cracks and soil subsidence in the filling soil. Natural ground may well be assumed to exhibit strong soil nonlinearity and partial pore-pressure build-up particularly in the vicinity of the viaduct foundation. The soil nonlinearity seems to have had strong influence on the dynamic response of the viaduct and the resonant frequency.