第 III 部門　An approach on verification of performance of a residential embankment due to the past earthquakes

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1. Introduction

Many geo-disasters were triggered by the 2011 off the Pacific coast of Tohoku Earthquake (M_W9.0). Among them, a large- scale slope failure occurring in Nankodai-6chome, Izumi Ward, Sendai City, Miyagi Prefecture, destroyed several residential houses[1](see Figs. 1 and 2). On the other hand, the slope failure was not occurred during the 2005 off Miyagi Prefecture Earthquake (M_J7.2). To clarify the triggering mechanism of this slope failure, it is great importance to evaluate the seismic performance of the fill slope at Nankodai Landslide site. In this study, not only the damage due to the 2011 main shock but also the non-damage due to the 2005 main shock was simulated based on Newmark's Sliding Block Method[2]. Moreover, pseudo-simulation was also carried out during the 1978 off Miyagi Prefecture Earthquake (M_J7.4).

2. Damage condition

Nankodai District is the large-scale housing area developed from 1962 to 1985. The distribution of ground crack occurrence at the slope of interest is shown in Fig. 2. The slope of interest is large-scale embankment with a dissected valley, and has confirmed a lot of significant residual deformation at shoulder and toe (see Blue seat areas in Fig. 1). Due to the seismic deformation, in a house where is close to the shoulder, serious damage with collapsed piers was confirmed (see Photo_C in Fig.2).

Not only the 2011 main shock but also the 1978 main shock has damaged the slope of interest. After the 1978 main shock, several countermeasures such as retaining wall, sheet pile and gabion were taken on the slope of interest. From these countermeasures, we can discuss that the ground- water level (see blue trace in Fig. 3) was comparatively high in the embankment slope. Due to the 2011 main shock, the retaining wall in northwest area has a residual deformation (relative displacement: 15cm) in N30°E direction (see Photo_A in Fig.2). On the other hand, during the 2011 main shock, the retaining wall in southeast area was collapsed by large-scale slope failure (see Photo_B in Fig.2).

3. Computation of residual displacement

Based on the above background, we evaluated the residual displacement of the residential fill slope based on Newmark's Sliding Block Method[2]. A 2-dimensional embankment model at the slope site of interest is shown in Fig. 3. In Fig. 3, shape of slope, soil layer and groundwater level were based on disclosure data by Sendai City Committee (2012). In particular, the various factors of the model were considered some of results of in-situ ground investigations. The characteristics of soil mechanics of the model are shown below. First, in sandy soil layers of B1 and B2, the wet unit weight is 19KN/m^3 and the saturated unit weight is 20 KN/m^3. Next, we determined the internal friction angle as 25 deg. (in B1 Layer) and 29 deg. (in B2 Layer). Based on the empirical relationship between cohesion c and ground depth h ; c(kPa) = h(m), finally, we determined the value of cohesion considering the ground depth dependency. Since a form of the slip surface was a non-circle according to the examination in Sendai City Committee (2012), this study also adopted the slip surface form (see Red trace in Fig. 3). Based on the determined conditions of the model, we calculated threshold acceleration as 296.5 Gal. Here, the threshold acceleration A_t is equivalent to the horizontal seismic intensity k_H (=A_t / 980Gal) from which the value of safety factor of the slope failure based on Janbu Method is almost 1.0. Moreover, the estimated strong ground motions by authors[3),4)] during the 2011, 2005 and 1978 main chocks (see Figs. 4(a), (b) and (c)) were used for input earthquake motions.

As shown in Fig. 4(d), we computed the time histories of sliding displacements for the 3 events based on the concept of Newmark's Sliding Block Method. As a result, the residual displacements are 35.8 cm (for the 2011 main shock) and 1.8 cm (for the 2005 main shock). This comparison result of the preliminary analysis coincides with the above-mentioned actual results of damage and non-damage in the fill slope. On the other hand, in Fig. 4(d), the slope of interest did not damage, supposing the 2011 Tohoku Earthquake was the same scale as the 1978 main shock.

4. Summary and conclusion

We computed the residual displacements of the residential fill slope at Nankodai landslide site during the past large-scale earthquakes based on the concept of Newmark's Sliding Block Method. As a future study, we will perform a dynamic FEM analysis considering excess pore water pressure.

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References

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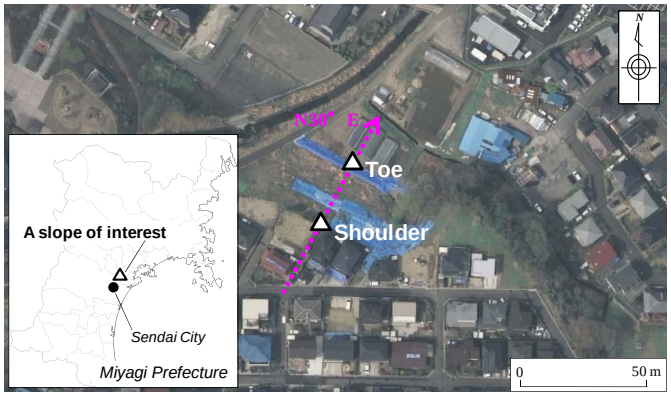

Fig.1 Location information at the slope site of interest.

Fig.2 Damage condition at the slope site of interest.

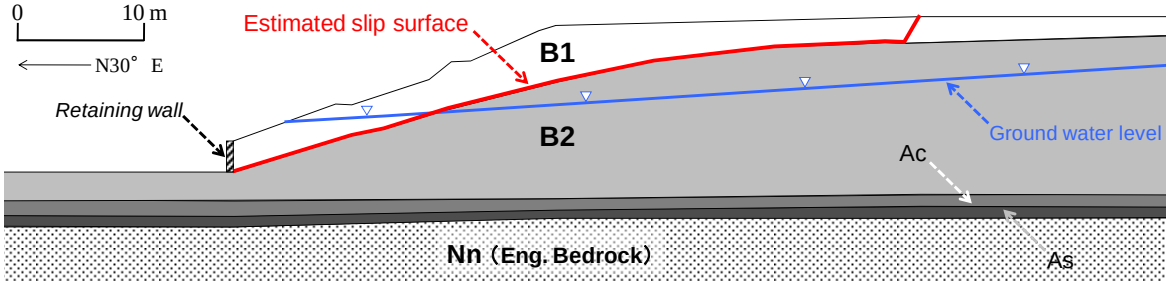

Fig.3 2-dimeisional model of the residential fill slope based on the existing examination by Sendai City Committee (2012).

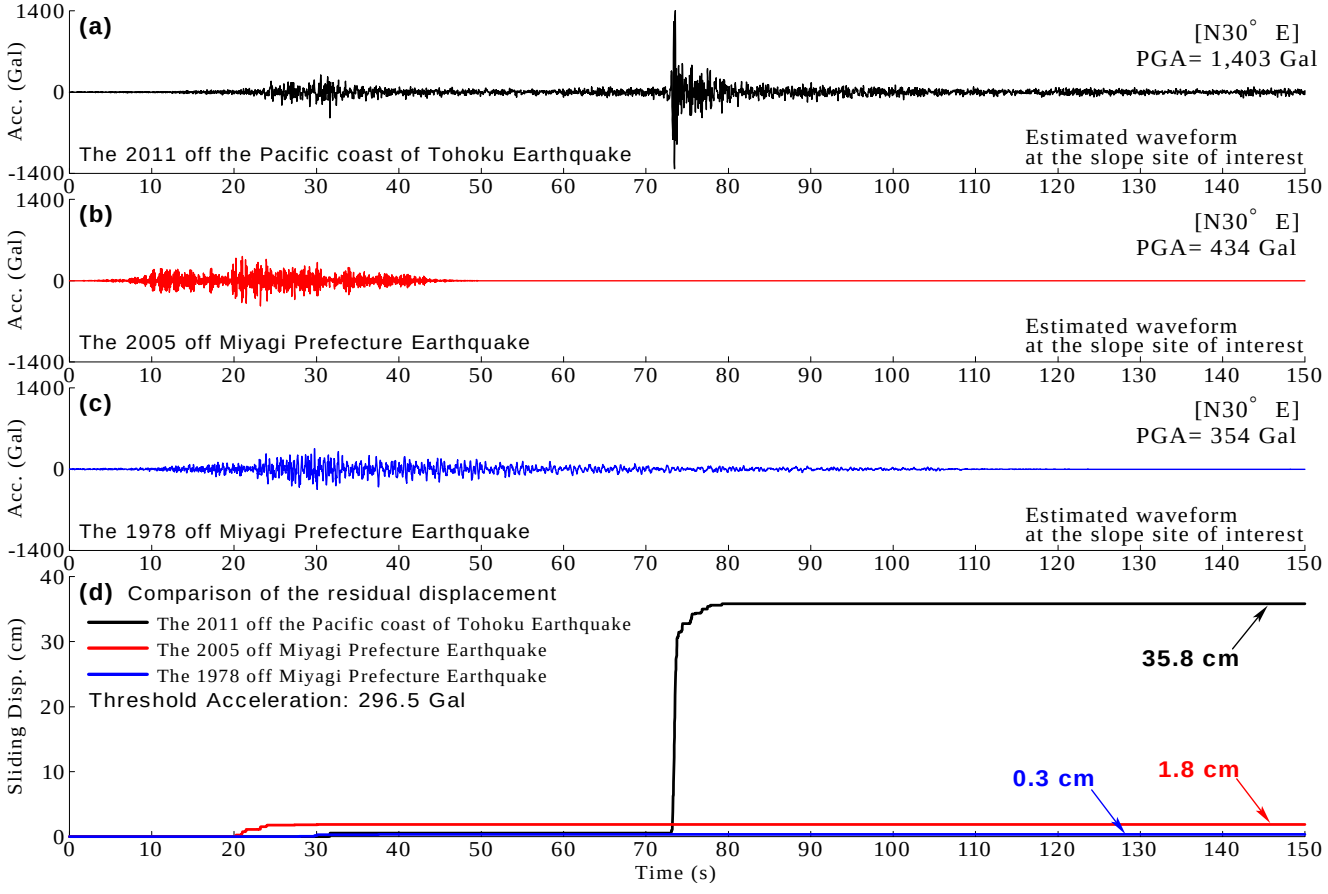

Fig.4 Computation of the residual displacement of the fill slope based on Newmark's Sliding Block Method due to the estimated ground motions.