SEISMIC DAMAGE ASSESSMENT OF RESIDENTIAL FILL GROUND IN THE EASTERN PART OF KYOTO BASIN

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ABSTRACT

Several earthquakes record that the residential fills always suffer severe damages. In order to know the seismic damage mechanism and evaluate the damage extent of residential fill ground, research is carried out on two fill grounds in the eastern part of Kyoto basin. The research works include field survey using surface wave explorations; mechanism analysis by using Fast Lagrangian Analysis of Continua (FLAC) software. Some remarkable conclusions are summarized as follows: In Jyodo-ji area, it is a residential fill on soft alluvium ground. The geological condition is back swamp. The thickness of surface fill soil is about 1~4 meters. The simulations show that the shear strain accumulates in the soft sediments. Sliding arc surface generates in the upper part of the ground. In Kiyomizu-dera area, it is a valley filled ground. The geological condition is hilly platform. The simulations show that fill soil parts have larger shear strain and displacement. With the groundwater level increasing, the acceleration amplification ratio slightly decreases, but the shear strain band and displacement zone become larger.

Keywords: Fill ground, Damage assessment, Surface wave exploration, Groundwater level effect

1. INTRODUCTION

With the economic development, the urbanization trend becomes more and more popular in the world. People move to cities and reclaim the ground for residential land. Some lands are coming from former marshland, pond or hilly areas. People flatten the ground by cut or filled soil. The changed landforms sometimes increase the damage potential, especially during earthquake. In recent year, there are about 10 earthquakes that caused residential fill ground damage (Kamai, 1995, 2005, 2008). So it aroused the concern of researcher. Previous research show that the reason for the residential fill ground damage includes intense seismic motion, terrain condition, groundwater level, site condition, etc (Yoshida, 2001;Okimura, 2006). But the seismic damage mechanism of fill ground is not well explained. So in this study, the seismic damage mechanism will be researched by using surface wave exploration and numerical analysis by Fast Lagrangian Analysis of Continua (FLAC) software.

2. SURFACE WAVE EXPLORATION ON RESIDENTIAL FILL GROUND

In this study, the ground conditions of two residential fill ground areas in the eastern part of Kyoto basin are introduced. They are Jyodo-ji area and Kiyomizu-dera area (Figure 1).

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2.1 Site condition of Jyodo-ji area

Jyodo-ji area is a small basin between Yoshita mountain on the west side and Kurodani hill on the south side. The basin is about 1km from south to north and about 500~600m from east to west. Shirokawa pass through this area from north to south. Most area is back swamp. It was farmland in 1922, and due to the urbanization, it becomes residential land now. During the 1995 Kobe earthquake, Jyodo-ji area suffered severe damage(Uemura, 1999). The location of damaged house concentrated in Baba machi and Minamida machi. There were about 40 houses' tiles fell down. Most of the damaged house located on the back swamp area. The depth of fill soil is ranged 1 to 4 meters. Geology columnar section shows there is a humus soil layer on the surface (KG-NET, 2008). The thickness of the soft mixture layer is more than 4 meters. The location of exploration sites and shear wave velocity distribution in two sites of Baba machi are showed in Figure 3. There are some parts of soft sediment in the ground. The average shear velocity is 130m/s.

Figure 1. Location of two residential fill ground in Kyoto city
A:Jyodo-ji area; B: Kiyomizu-dera area
(Uemura, Y. 1999)

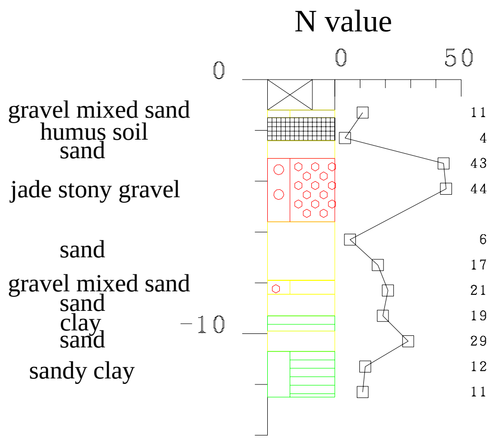


Figure 2.Geology columnar section in Baba machi
(KG-NET, 2008)

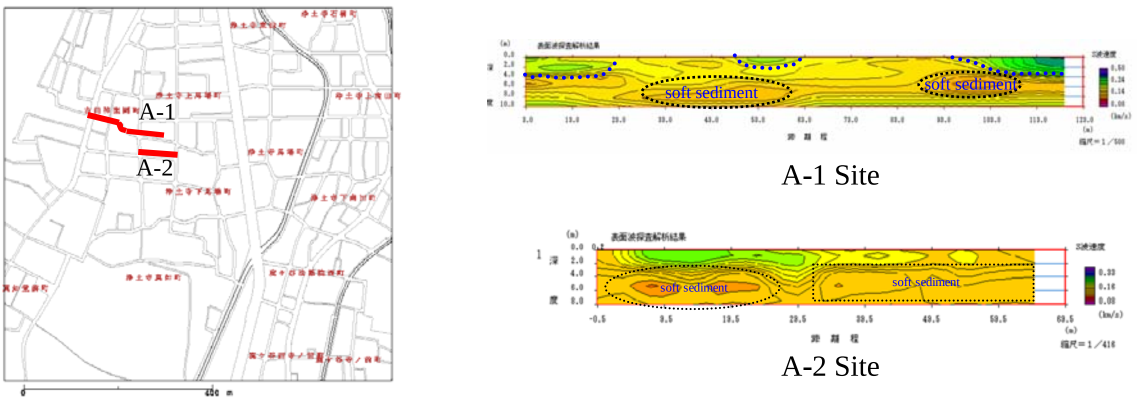


Figure 3. Exploration Location and shear wave velocity distributions in two sites of Baba machi

2.2 Site condition of Kiyomizu-dera area

Kiyomizu-dera area is hilly platform. There are some deep valleys from east to west. Some lowland of valley is residential filled ground. Despite little damage in 1995 Kobe earthquake, some damaged house can be seen in new developed area (near B-3 site). From the exploration results, fill ground can be seen clearly in B-2 and B-3 sites (Figure 4).

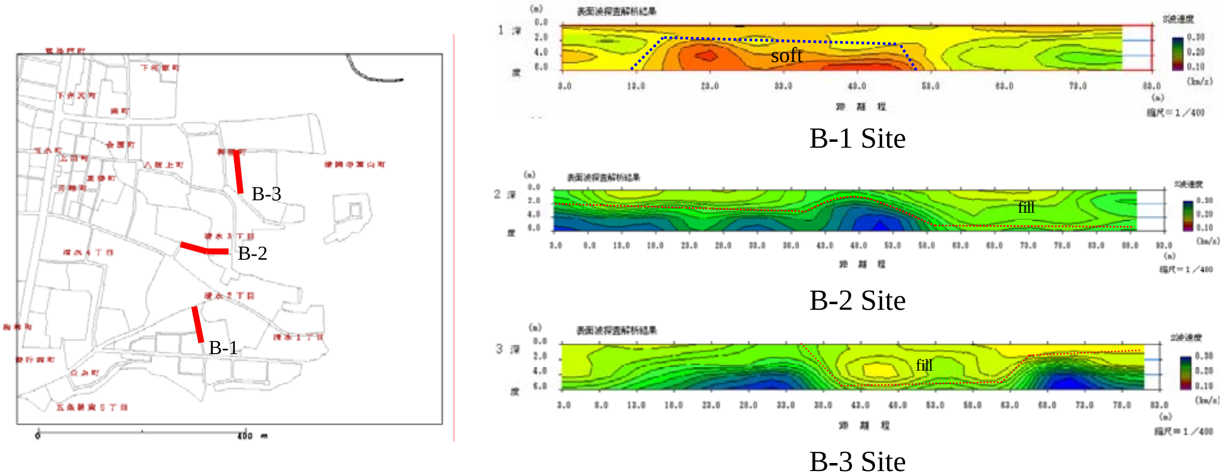


Figure 4. Exploration Location and shear wave velocity distributions in in Kiyomizu-dera area

3. SEISMIC RESPONSE ANALYSIS ON RESIDENTIAL FILL GROUND

Seismic response of the fill ground in Jyodo-ji area and Kiyomizu-dera area are analyzed by FLAC software. The potential damage mode of the ground will be discussed.

3.1 Analysis results of fill ground in Jyodo-ji area

According to the surface wave exploration results (Figure 3) and geology columnar sections results, FLAC model of A-1 site is set up as Figure 6. Water level is 3 meters below the ground level. Soil model 1-5 uses the Finn model and soil model 6 uses the Mohr-Coulomb model (Figure 6). Horizontal boundary uses free field boundary. The Hyogo-ken-Nanbu earthquake ground motion record obtained at Higashiyama (in Kiyomizu-dera area) in Kyoto city is used as input acceleration time history (Figure 5 Nakamura, Y., 1996,).

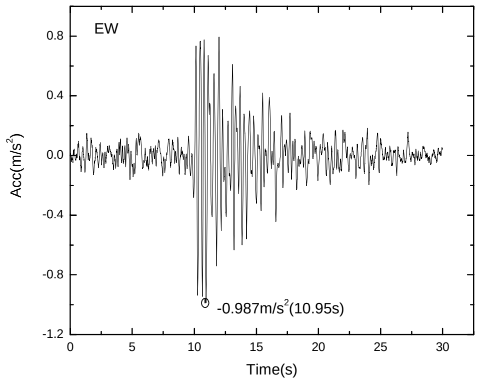


Figure 5. Input acceleration time history

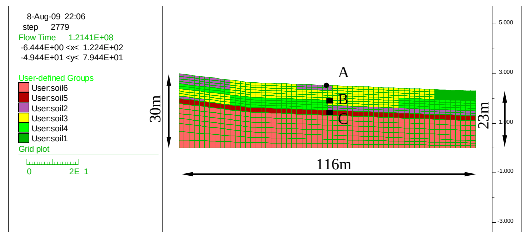


Figure 6. FLAC model of A-1 site

The ground amplified the seismic motion about 2.3 times (Figure 7). Both B and C elements have high pore pressures during earthquake (Figure 8).There is a shear strain band generated from the upper to the middle of the ground (Figure 9). The upper part has slide potential (Figure 10, the part in dot line).

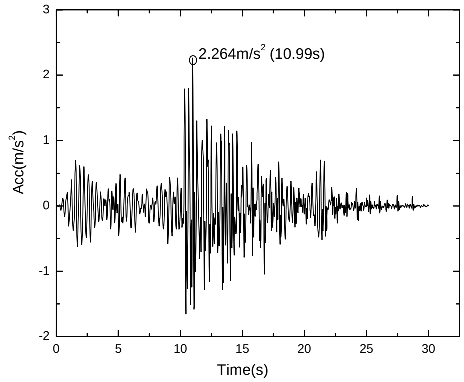


Figure 7. Acceleration response at the ground surface

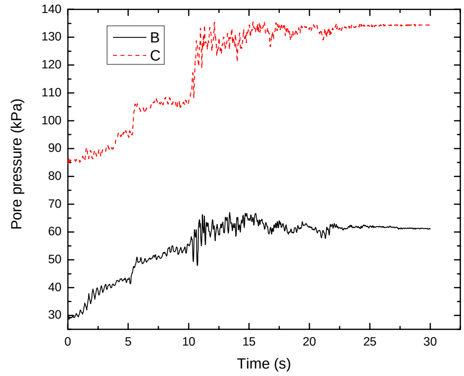


Figure 8. Pore pressure development at element B and C

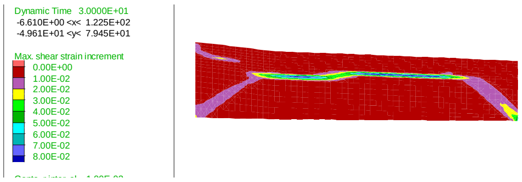


Figure 9.Shear strain increment

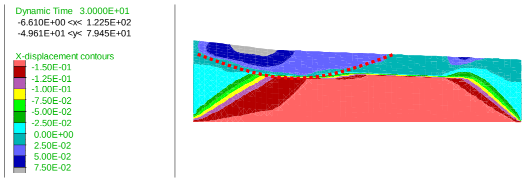


Figure 10.Horizontal displacements

3.2 Analysis results of fill ground in Kiyomizu-dera area

3.2.1 B-2 Site

FLAC model of B-2 site is seen in Figure 11. The geological condition of the ground is valley filled ground. Water level, horizontal boundary and the input motion are same as the input of A-1. The ground amplified seismic motion 3.97 times (Figure 12). From the top to the middle part of the ground, there is a shear strain band generated. The upper part has large horizontal displacements.

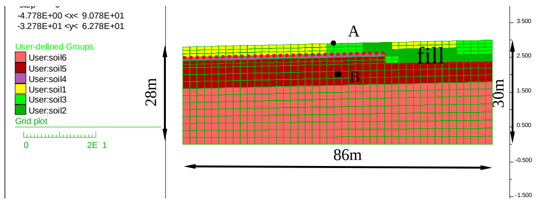


Figure 11. FLAC model of B-2 site

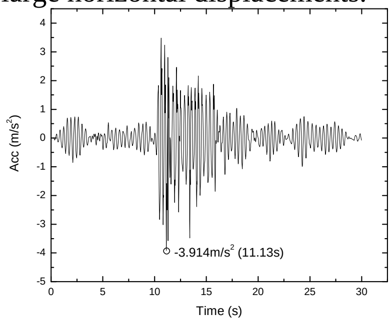


Figure 12. Ground acceleration response

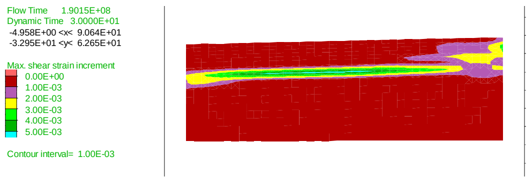


Figure 13. Shear strain increment

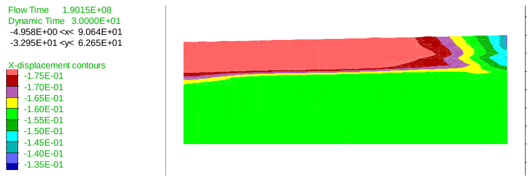


Figure 14.Horizontal displacements

3.2.2 B-3 Site

FLAC model of B-3 site is seen in Figure 15. Water level, horizontal boundary and the input motion are same as the input of A-1. The ground amplified seismic motion 3.87 times (Figure 16). In the middle part of the ground, there is a shear strain band generated (Figure 17). The fill soil part has large horizontal displacement (Figure 18). The results can well explain why there are a lot damaged houses in this area.

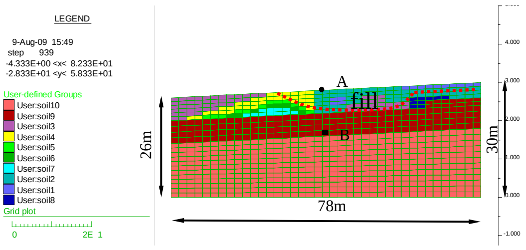


Figure 15. FLAC model of B-3 site

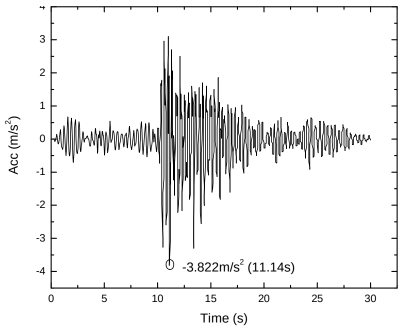


Figure 16. Ground acceleration response

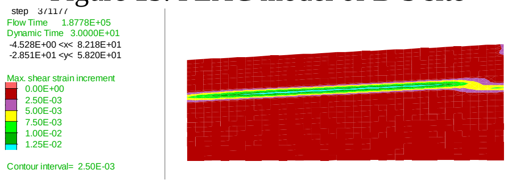


Figure 17. Shear strain increment

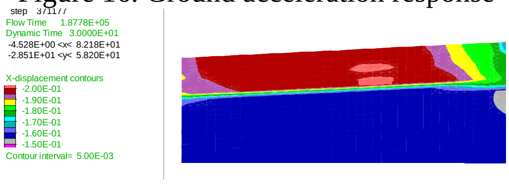


Figure 18.Horizontal displacements

4. GROUNDWATER LEVEL EFFECT ON SEISMIC STABILITY OF FILL GROUND

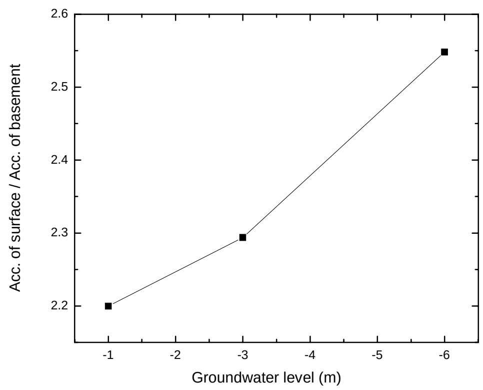
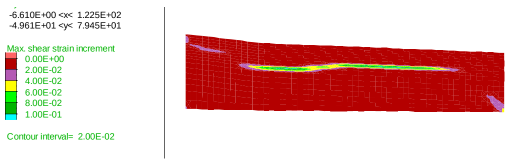
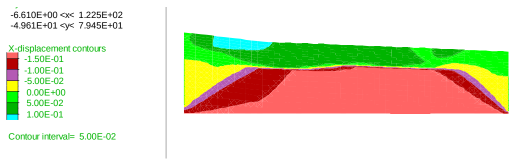


Figure 19. The relation between groundwater level and acceleration amplification ratio

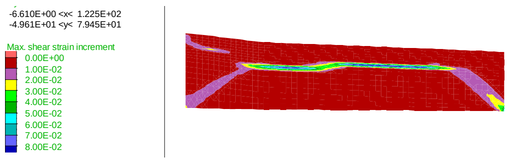
A-1 site is used as calculation model. All the calculation parameters are same as before except groundwater level. The groundwater level is changed into 1, 3 and 6 meters below ground surface. Results are seen in Figure 19~21. With the groundwater level increasing, the acceleration amplification ratio slightly decreases, but the shear strain band and displacement zone become larger. When the ground water level is high, more area will have high pore pressure. When liquefaction occurred, on the one hand, liquefaction ground behaving as an isolation cushion can slightly reduce the seismic motion; on the other hand, liquefaction lowers the effective stress and it can induce large horizontal displacement.



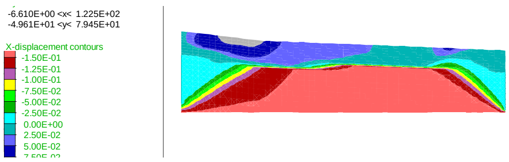
Groundwater level(GL) -1m



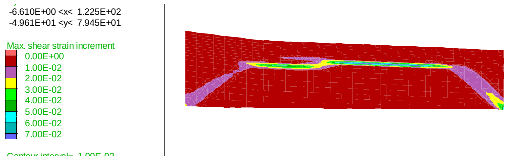
GL -1m



GL -3m

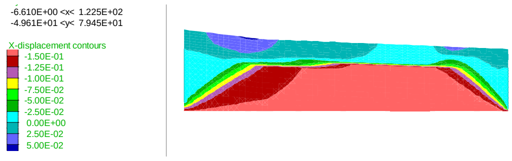


GL -3m



GL -6m

Figure 20.Shear strain increment



GL -6m

Figure 21.Horizontal displacements

5. CONCLUSIONS

In order to evaluate the seismic damage mechanism of residential fill ground, field survey using surface wave exploration, mechanism analysis by FLAC software have been carried out on two residential fill ground in the eastern part of Kyoto basin. Some remarkable conclusions are summarized as follows:

(1) In Jyodo-ji area, it is fill land on soft ground. The geological condition is back swamp. It is former farmland changed into residential land. The seismic simulation results show that the shear strain accumulates in the soft sediment. Sliding arc surface generates in upper part of the ground. High pore pressure generates and the acceleration amplification occurs during the earthquake. The analysis results are coincident with the real disaster condition.

(2) In Kiyomizu-dera area, it is residential fill ground in hilly area. The geological condition is hilly platform. Despite this area suffered almost no damage during the 1995 Kobe earthquake, some cracks can also be seen on the walls of houses in newly developed fill ground. The analysis results show that the shear strain band accumulates in the ground. Fill soil parts have larger shear strain and displacements.

(3) With the groundwater level increasing, the acceleration amplification ratio slightly decreases, but the shear strain band and displacement zone becomes larger.

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