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GROUND LIQUEFACTION IS NOT DANGEROUS FOR HUMAN LIVES

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SUMMARY

The casualties by the liquefaction of the ground in the past earthquakes for 60 years in Japan are only six persons and more than ten thousands by other causes.
It seems to be the following two reasons why we have so small number of casualties by the liquefaction of the ground like this.
1. The S wave of earthquake ground motion does not propagate into liquid, therefore, the earthquake motion on the surface of the ground upon the liquefied layer is not so severe.
2. Although the ground liquefaction causes the phenomenon of inclination, subsidence, and float-up of the structure, the process of these phenomena goes very slowly, therefore, people can have the time to refuge from the breaking structure.

Although the loss of human lives due to the ground liquefaction are negligibly small, the economical loss due to such as the inclination or subsidence of structures occur by the liquefaction, however, the amount of those loss is not so much, because the economical damage of liquefaction occurs not frequently, but once every two or three years, and it is limited in narrow areas in Japan.
Therefore, I would like to propose not to conduct the liquefaction countermeasures of ground all over the country because it is not economical.
Of course, the sufficient liquefaction countermeasure should be done on such structure as the earth dam near the city by the liquefied collapse of which a lot of human lives would be lost.

INTRODUCTION

The casualties due to the liquefaction of the ground in the past earthquakes for 60 years in Japan, are only 6 persons in spite of more than ten thousands due to other causes, such as the collapse of houses and big fires after earthquake, etc..
The reason why the casualties due to the liquefaction are so few, is investigated in the following section.

NUMBER OF CASUALTIES DUE TO LIQUEFACTION IN PAST EARTHQUAKES IN JAPAN

In these 60 years, number of casualties by the main cause of liquefaction is only the following six persons;
One person in 1948 Fukui earthquake (3895),
Two persons in 1964 Niigata earthquake (26),

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And
Three persons in 1995 Kobe earthquake (more than 5500).

The number in the parenthesis indicates the number of casualties in the earthquake due to all kinds of causes, such as big fire after the earthquake and the collapse of the building, and so on. We have several other examples of earthquakes which the liquefaction became a trigger of the disaster such as debris flow, and we had many casualties in these earthquakes. However, though the liquefaction might become a trigger of the disaster in them, the liquefaction countermeasure for the disaster has not been done till now and it will be impossible to make the countermeasure even in the future. Therefore, this problem shall not be considered.

WHY IS THE NUMBER OF CASUALTIES BY THE LIQUEFACTION FEW?

S wave in the earthquake ground motion can not pass through the liquid

The usual structure is strong against the vertical load including the dead load at the design of structure and it has big allowances in the vertical direction. However, there are small allowances in the horizontal direction, since only seismic and wind loads are considered. Therefore, the S wave which shakes the structure horizontally, is the wave which destroy the structure, among the earthquake ground motions. S wave can not transmit in the liquid in which the shear reaction is not generated, as the S wave is the wave in which shear strain transmits in the ground.

In 1995 Kobe earthquake, Kobe municipal office obtained the earthquake records on the surface and underground (-76m) in array observation (Fig.1) at the reclaimed and liquefied land.

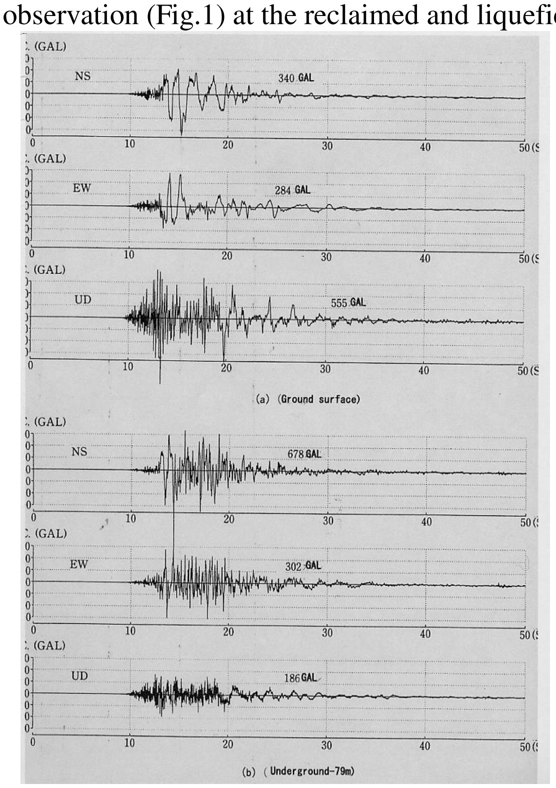

Fig.1 Accelerograms at the ground surface and underground (-79m), In the liquefied reclaimed land, recorded by Kobe municipal office Kobe earthquake 1995, Japan

Only the horizontal motion (S wave) on the surface is approximately a half less than the one at the level – 79m underground, though the vertical motion (P wave) on the surface is approximately two times more than underground. This phenomenon indicates that the S wave is difficult to propagate into the liquefied layer just beneath the surface.
The rapid destruction of the structure by the earthquake ground motion, specially by S wave, is seldom occurred, since the horizontal motion of the ground surface remarkably decreases by the liquefaction as shown in Fig.1.

INCLINATION, SUBSIDENCE AND FLOATATION OF THE STRUCTURE BY THE LIQUEFACTION ARE GENERATED VERY SLOWLY

In case of ground liquefaction, the rapid destruction of the structure by the intense horizontal vibration is not generated, because the most of S wave does not reach the surface. Although the vertical ground motion (P wave) is amplified in the ground surface layer, its duration is short and does not give a serious damage on the structure. Then, the destruction of structure due to liquefaction will be the slow fracture such as inclination, subsidence, floatation, etc..

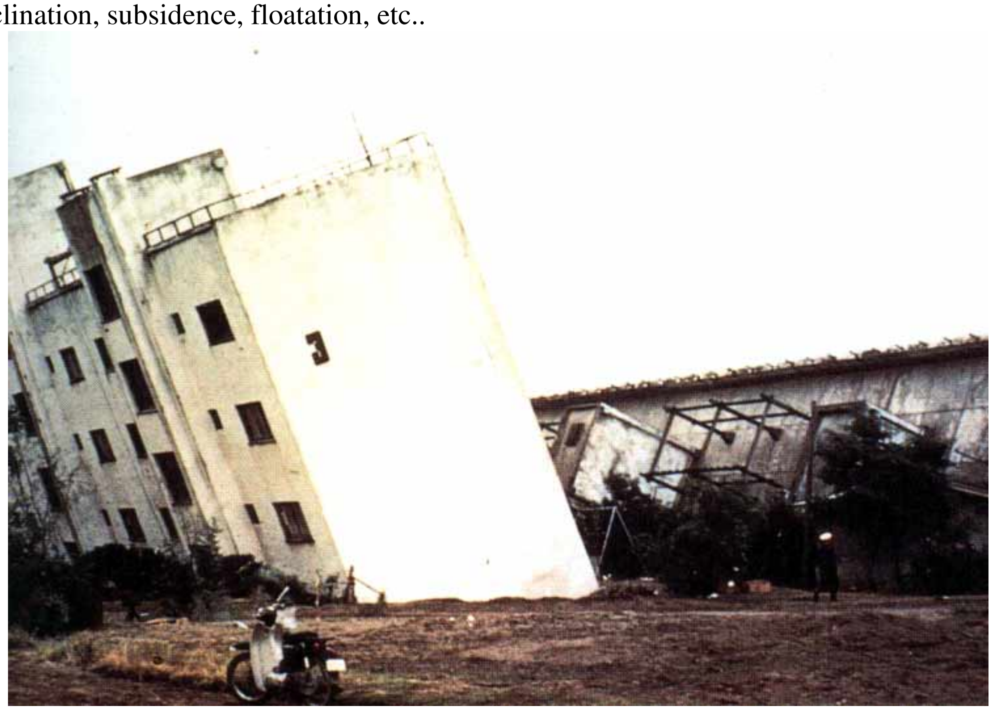

Fig.2 Tilted RC apartment house by the liquefaction, Niigata earthquake (M7.5) Japan, 1964

The four story building of apartment house was located in the sandy alluvium of the riverside. It tilted as shown in Fig.2 by the liquefaction of the ground. In spite of severe inclination, we could not find any crack either anywhere of the building. The window glass which is most easy to break at the earthquake, was not broken either. The residents of this building were safe by refuging. It took 10 minutes for the building to have tilted like the Fig.2, therefore, the resident had enough time to refuge from the building.

Fig.3 The bridge pier sank down by the ground liquefaction,
Luzon earthquake (M7.8) Philippines, 1990

It seems that the basement of the bridge pier is not good. The blown sand and sand volcano appear in front of the pier. It is recognized that this phenomenon also progressed very slowly.

Fig.4 The float-up of the manhole,
Tokachi-oki earthquake (M8.0) Japan, 2003

The manhole also stands out on 1.5m by the liquefaction of the ground.
These destruction occurred very slowly by next reason. In short words, the sand particles do not disappear in the liquefied sands, but float in water. Therefore, the sand particle in the vicinity which contacts the structure is compressed by a little displacement of the structure, then the contact between sand particles is restored, and the resistant force of sand particles to the structure increases. The little displacement of the structure generates the increase of the resistant force, therefore inclination, subsidence, floatation, etc. advances slowly.

Human lives are lost by the rapid destruction of the structure
Major victims during earthquakes in Japan have been brought by the rapid destruction such as collapses of dwelling houses. In the slow fracture events such as inclination and subsidence of the structure, people are not killed, because they have time to refuge.
Two persons of three deaths by the liquefaction in Kobe earthquake 1995, were the drivers of the cars running on the bridge girder which fell down by the horizontal displacement of the bridge piers due to liquefaction. Since the fall down of bridge girder was rapid, it causes death of drivers, even if the horizontal displacement of the bridge pier was slow. By the above reason, it is usually considered that the human lives are not lost by the liquefaction of the ground.

LIQUEFIED GROUND IS A NATURAL SEISMIC ISOLATOR

It seems that a lot of people survived by the liquefaction of the ground in Niigata earthquake of Japan 1964 (M7.5). Its epicenter was in Awashima island approximately 40km off from the Niigata city. The focal area seemed to contain a part of Niigata province. Whole area in the Niigata city suffered the damage by the liquefaction. However, the number of casualties in Niigata was 13 and it was much less than expected from the magnitude 7.5. The liquefied ground layer, as mentioned previously, cuts the S wave which destroys the structure rapidly. In short words, it does work as a kind of a seismic isolator. The fact that the whole area of the Niigata city was liquefied, means that the city got the large seismic isolator beneath it. However, this seismic isolator can not protect the structure from the slow fracture such as inclination, subsidence, and floatation, etc.. There would be only few casualties because these slow fracture does not loose the human lives.

Recently the research activities utilizing the liquefaction phenomenon as the seismic isolator to the individual structure [1], however, it needs money.

The ground which will be liquefied at an earthquake and protect human life, might be equivalent to the "free" seismic isolator.

Liquefaction does not cause loss of human life, but economical loss

The economical loss occurs, as inclination, subsidence, floatation of the structure occurs by the liquefaction.

The major purpose of the aseismic countermeasures is to protect human lives, therefore, if the ground liquefaction does not cause the loss of human life, it is useless to have a countermeasure against the liquefaction.

Generally speaking, we make a countermeasure on the structure in order to be able to survive from the earthquake. We do not have to make a countermeasure against something, if we do not loose our lives, though something happen. Moreover, the possibility that the economic loss occurs, is very little. The liquefaction damage by the earthquake occurs only once in several years all over Japan and the damage is also limited to very small area.

For example, though the liquefaction would occurred in the reclaimed land of the Tokyo bay in Kanto earthquake 1923, we have never had the liquefaction in Tokyo these 80 years till now. Considering one site, the earthquake comes again every one hundred years or so, even in Tokyo where the earthquakes most frequently have attacked. At the time of Kanto earthquake, economical damage was limited to very small areas along the sea coast and the rivers.

WE HAVE TO MAKE THE SUFFICIENT LIQUEFACTION COUNTERMEASURE TO THE STRUCTURE WHICH IS EXPECTED MANY CASUALTIES IF IT IS DESTROYED

For example, we have to make the sufficient countermeasure against the liquefaction to the embankment to prevent the Tokyo under-sea-level area from the sea water. Otherwise, if it is broken, the sea water come in the under-sea-level area, downtown of Tokyo city unlimitedly and it would come into the subway and the almost whole subway network of Tokyo would be submerged and many people will die.

The petrochemical complex is often being constructed on the reclaimed land, therefore, this kind of reclaimed land should be constructed not to liquefy.

The sufficient countermeasure against the liquefaction would be necessary also for the reservoir earth-dam in the downstream of which is located a large city (Fig.5).

Fig.5 Liquefied Van-Norman earth-dam,
San Fernando earthquake (M6.5) USA, 1971

The collapse of the dam was caused by liquefaction under the water in the reservoir. The dam was not completely collapsed, therefore, the water of the reservoir did not go downstream fortunately. Many people live downstream of the dam, therefore, if the dam was completely collapsed and much water of the reservoir had come down the residential area, then they would be suffered the catastrophe.

REFERENCES

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