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Review on Seismic Liquefaction of Seabed Soil

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ABSTRACT: Seismic liquefaction can cause instability and deformation of subsea soil, and affect the use and safety of offshore engineering structures. The characteristics of liquefaction damage of submarine soil are analyzed through an example of earthquake damage of submarine liquefaction. The research methods of liquefaction and lateral displacement of soil after liquefaction are briefly introduced and commented. The shortcomings and problems of current research on liquefaction and lateral displacement damage of submarine earthquake are pointed out.

1. Introduction

Under seismic and dynamic loads, saturated loose sand (silt) soil loses its shear strength due to strong vibration, which makes sand particles in suspension state, resulting in liquefaction of foundation failure. As a ground damage effect caused by earthquake, liquefaction is a highly destructive regional geological hazard. A large number of earthquake hazard investigations and earthquake hazard cases show that soil liquefaction under earthquake may cause great direct and indirect economic losses, such as the destruction of highways, railways and bridges, the settlement, inclination and destruction of buildings or houses, the liquefaction of large areas of artificial islands, the closure of runways caused by liquefaction of airports, and so on.

Before the 1960s, people had not realized the seriousness of site soil liquefaction hazards to buildings after strong earthquakes. A large number of projects were constructed on liquefied site soil. Saturated loose sand and silt are widely distributed in coastal, lakeshore, alluvial plain, flood plain and low terrace areas. During strong earthquakes, these sites are prone to liquefaction in large areas, causing regional hazards. The buildings, bridges, roads, ports, farmland, dams and other engineering facilities located on these liquefied sites will inevitably be damaged. After the 1964 Shinju earthquake in Japan, liquefaction of the site caused great damage to various engineering facilities. Among them, more than 2130 buildings collapsed due to foundation failure, 6200 buildings were seriously damaged and more than 31 000 buildings were slightly damaged. In the same year, when the Alaska earthquake occurred in the United States, Portch City had to relocate because of the liquefaction of sand and the submergence of high tide. So far, liquefaction is still the focus of geotechnical seismic engineering research, and also the focus of engineering construction.

Foundation liquefaction is a form of foundation failure, that is, the state of foundation soil changing from solid to liquid. Soil liquefaction mainly occurs in saturated loose powder, fine sand or silt. Slighter liquefaction will reduce the strength of foundation soil, but in severe cases it will completely fail, which is shown by water spraying and sand-blasting, ground subsidence, ground cracks, lateral expansion and slippage, etc. Buildings built on liquefied foundation soil may appear various forms of water-blasting and sand-blasting, such as floating of underground structures, house cracking, overall inclination, house dumping, etc. 1.1.



What is the phenomenon of water spraying and sand blasting? How did it come into being? Saturated silt and sand are complex of sand particles and water. Before the earthquake, the framework of sand particles bears external forces, while water bears only hydrostatic pressure. At this time, the foundation soil is stable, but after repeated earthquake vibration, the sand particles move and the arrangement state is changed, but the volume remains unchanged. The vibration is transferred from the original sand grain skeleton to the water. In this way, the pore water pressure increases sharply. Finally, because the pore water pressure is greater than or equal to the total stress of the soil, the soil structure is completely destroyed, sand particles are suspended in the water, and saturated soils are thus liquefied and sprayed out at a weak crack site. Therefore, the phenomenon of water spraying and sand blasting is the most direct evidence to determine whether liquefaction of foundation soil occurs.

During the Wenchuan earthquake, water-spraying and sand-breaking occurred in four different areas, namely Mianyang, Chengdu, Deyang and Ya'an. Water-spraying height exceeded 10 m. For example, in Tumen Town, Anxian County, Mianyang area, Yongshou Village, Dujiangyan, Chengdu area, water-spraying height reached roof antenna frame. In Mianzhu Xiangliu Village, Deyang area, water-spraying height exceeded two electric poles; water column height was above 10 m. This phenomenon of water spraying at a height of 10-15 m is rare in previous earthquakes. According to the basic principle of liquefaction, it should be caused by liquefaction of deep soil. In addition, the liquefaction spraying time of Wenchuan earthquake generally lasts only a few minutes, but there are also some relatively long ones. For example, in Xinlian Village of Leshan City, the phenomenon of water and sand blowout lasted for 3 months. In Siyuan Village of Shifang City and Shuangshiqiao Village of Guanghan City, there was still water spraying and sand blasting more than a month after the earthquake. In Wenchuan Earthquake, water and sand spraying took the form of volcanic sand mounds and beaded sand-blasting holes. Compared with previous earthquakes, the liquefaction sand blasting volume of this earthquake is generally less than 5 cubic meters, but there is a large amount of sand blasting in places with pools and wells. For example, a swimming pool of 50m *20m *2m in Siyuan Village, Shifang City, dried up before the earthquake, liquefied at the epicenter caused the bottom of the pool to arching, filled with sand-water mixture, and the swimming pool was only 1 m deep after the earthquake. In Xinglong Town of Mianzhu City, more than 60 wells were buried after the earthquake, and there were a lot of sand fillings in the wells.

During the Haicheng earthquake, a large number of water and sand spraying occurred in Panjin area to the west of the epicenter, which usually started several minutes after the main shock and lasted for 5-6 hours or even days. A mixture of sand and water 3-5M high is ejected, forming many elliptical and circular pits with diameters of 3-4m to 7-8m and depths of tens of centimeters to several meters, causing serious damage to local transportation and water conservancy facilities, farmland, houses and underground pipelines.

During the 9.21 Chi Chi earthquake in Taiwan, in the high beach area on the south side of the Datuixi Estuary in the town of Yangang, Zhanghua County, after the earthquake, soil liquefaction was widespread, and water and sand eruption was formed. The shape of the eruption was like a volcanic crater, which overflowed radially from the bottom of the mud and sand.

2. SEISMIC DAMAGE EXAMPLES OF SEA-BOTTOM EARTHQUAKES

Earthquake induced liquefaction of land saturated sand and silt foundation and caused structural damage. Similarly, earthquakes can also cause serious damage to marine engineering sites. For example, the 1995 Greek Gulf earthquake with magnitude 6.1, Papatheodorou and Ferentinos conducted a field survey of the damage to the seabed. It was found that the damage mainly occurred within 5-6 meters of the upper seabed, and the slope of the seabed was 0.20-230. The main forms of damage were landslides, soil sliding, sediment flow and caving. Sand phenomenon, the main cause of damage is the liquefaction of seabed soil caused by earthquake.

With the development and utilization of the ocean, the number of offshore engineering structures such as offshore platforms and submarine pipelines is increasing. Therefore, the stability of the subsea soil has attracted more attention. Within the continental shelf of the seabed, the instability deformation

of the seabed soil will produce larger displacement and force, which seriously threatens the safety of coastal and offshore engineering, and may cause accidents such as the sinking, slipping, dumping of offshore platforms and the displacement and floatation of submarine pipelines, resulting in serious economic losses. For example, the 1982 Gulf of Mexico hurricane triggered submarine landslides that toppled two of the world's deepest oil production platforms at that time. The economic losses caused by equipment costs alone amounted to more than \$100 million. Another example is the Bohai No.2 drilling platform in China, from 1973 to 1979, there was one inclined subsidence and nine sliding bodies due to submarine landslides, and in 1995, Shengli No.3 drilling platform in the Bohai Sea lost its working capacity due to the liquefaction of foundation sand and was forced to move well positions, which caused huge losses. Therefore, there is an urgent need for seismic liquefaction and induced slip assessment of offshore engineering sites in engineering circles, and new research results are eager to provide reference for site selection and seismic design of offshore engineering structures.

3.CHARACTERISTICS OF EARTHQUAKE LIQUEFACTION DAMAGE IN SEA-BOTTOM SOIL

The marine continental shelf was once a part of the land. Because of the fluctuation of sea level, the nature of the old seabed soil at the edge of the land was similar to that of the land, and it became a shallow sea environment. During a period of time, it was submerged below the sea level.

There are many similarities. Through the example of seabed earthquake damage, we can see that the seabed soil has its particularity when it is subjected to earthquake in the marine environment. [1]: (1) During the earthquake, the saturation state of the seabed soil, the underconsolidation caused by the sedimentation process and the shallow gas of the seabed all make the seabed soil more liable to liquefaction. (2) The seabed with a gentle slope or even less than 1 can also be damaged by lateral displacement. When the seabed surface liquefies, due to the action of waves and currents, the soil is liable to form mud flow after liquefaction, and the suspended body diffuses to a longer distance. When liquefaction occurs in some soil layers below the seabed, the pore water pressure dissipates much slower than on land, and the strength recovers slower, which makes the scale of lateral displacement larger. If the liquefaction is converted into mud flow, it will cause greater regularity. Slip of mode. (3) Earthquake liquefaction causes sudden landslides of large-scale seabed soils, which may cause tsunamis, such as the 1929 Grand Banks undersea earthquake.

In addition, when the seawater depth is less than 150 m, the wave loads acting on the seabed soil layer will also cause the increase of seabed pore water pressure; it is difficult and expensive to sample the seabed soil, and it is not easy to obtain high-quality soil parameters. Therefore, the study of seismic liquefaction and lateral displacement damage of submarine soil under earthquake has more influencing factors and difficulties, such as dynamic characteristics of submarine soil and pore water pressure model, additional action of wave load and soil failure process after liquefaction will be the key issues in this study.

4. Study on the Consequences of Earthquake Liquefaction Damage of Seabed Soil

Large ground displacement caused by liquefaction includes seismic subsidence and lateral expansion, both of which can cause structural damage. They are one of the main forms of seismic damage in liquefied area, such as highway, railway, bridge, dam, underground engineering and lifeline engineering. In the field of geotechnical seismic engineering, the emphasis on large ground displacement after earthquakes began with Professor Hamada's investigation of large ground displacement after earthquakes in the central part of the Sea of Japan. The research work on large ground displacement mainly includes the following aspects:

(1) Accumulate data, test and predict results by using seismic field investigation, and find out problems and solve them. In this regard, Hamad, Sasaki, Youd and Perkins, Zhang Jianmin and Liu Huishan have done fruitful work.

(2) Laboratory experiments were conducted. Vaid and Thomas have studied Canadian Fraser sand through triaxial test, Yasuda et al. have done torsional shear test and shaking table test for Japanese

standard sand, Meneses et al.

5. Summary

With the development and utilization of the ocean in the 21st century, people need to know more about the ocean and ocean engineering, although the disaster environment of saturated sandy land including land and ocean has been actively prevented.

Seismic liquefaction, stability of submarine slope and large deformation analysis of liquefaction have yielded some results. However, the dynamic characteristics and pore pressure model of submarine soil are still lacking. The study of ocean wave loading, liquefaction of submarine soil and lateral displacement of instability also needs to integrate the knowledge of geotechnical seismic engineering, soil dynamics and wave mechanics, and draw lessons from the research results of seismic liquefaction on land. Only in this way can we better understand the mechanism of liquefaction damage of subsea soil and promote the development of marine geotechnical seismic engineering as an interdisciplinary research discipline.

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