Chapter 2

Introduction

Chan Chan archaeological site in North Peru

2.1 Objectives of Earthquake Geotechnical Engineering

Earthquake geotechnical engineering is concerned with the following topics:

1. Prediction of ground motion during earthquakes
2. Prediction of residual deformation of ground and earth structures that remain after shaking
3. Study on stress–strain–strength characteristics of soils undergoing cyclic loading
4. Subsurface exploration by generating and observing propagation of ground vibration
5. Safety and/or satisfactory performance of structures during earthquakes
6. Application of knowledge to ground vibration caused by machine and traffic loading among others

In the past experiences, such earthquake-related damages as loss of human lives and properties as well as malfunctioning of facilities were induced by either a total collapse of structures or their unacceptably large deformation. Those collapse and deformation in turn were induced by either a strong shaking or a ground deformation that is not recovered after an earthquakes and remains permanently. Therefore, the topics (1) and (2) shown above are concerned with the prediction of the extent of damage.

It has been found that the ground shaking and the residual deformation that remains after shaking are strongly dependent on the stress–strain behavior of soils. Since soil is a nonlinear material, there is no proportionality between stress and strain. The deformation characteristics, and of course the strength, vary drastically with

- The magnitude of effective stress that stands for the contact forces among soil grains
- History of stress application in the past (normal or over consolidation)
- Age of soil
- Rate of loading (to some extent)
- Material strength of soil

among others. Thus, the basic understanding of soil behavior requires us to do much efforts experimentally. Consequently, many stress–strain models of soils have been proposed by a number of research people.

Even though an appropriate stress–strain model may be available for an analysis, identification of soil parameters at a specified site is further difficult. Practice runs tests in the field or collects soil specimens of good quality (this is already a big topic of study) for laboratory testing. The employed model may or may not be able to handle the complicated stress–strain behavior. The collected information may be representative of the whole ground (case of uniform ground) or indicates the behavior of a small specimen (case of heterogeneous ground).

To date, many computer codes have been developed that can calculate the earthquake shaking of ground and earth structures. They appear to be reasonable when the studied ground condition is relatively stiff. It means that the prediction is reasonable when the strain in soil is small and the nonlinearity is not significant. Conversely, computation on soft soil deposits is still difficult.

There is no general way to relate the predicted nature of ground shaking to the extent of damage. Many kinds of structures are of different causes of damages, which cannot be taken care of by a single or a limited number of seismic parameter(s).

In summary, there are still so many problems in earthquake geotechnical engineering that require further studies. It should be borne in mind that what are being discussed today at many occasions might be discarded in the next decade.

2.2 Geotechnical Problems Encountered During Earthquakes

Recent earthquake events have been studied in detail and many points have been made. Consequently, it has been found that two phenomena should be studied, namely amplification of shaking and liquefaction.

1. Problems induced by shaking include the following issues:

Amplification of motion in soft alluvial deposits 軟弱沖積層における地震動の増幅
Effects of local soil conditions and topography on amplification 地盤条件や地形が地震動増幅度に及ぼす影響
Permanent (residual) deformation of earth structures 土構造物の永久変形（残留変形）
Landslide 地すべり
Different causes of seismic failure in different types of facilities 地震被害の原因は施設の種類によって異なる,
for instance, inertia force 慣性力, deformation of surrounding soil 周辺地盤の変形, etc.

Conventionally, earthquake engineering has been working on the intensity of acceleration 加速度 at the bottom of surface structures. This is because d'Lambert principle states the equivalence of the acceleration and the inertia force. It is, however, apparent that the acceleration does not account for the deformation/strain of the ground. Some people, therefore, prefer to use the earthquake velocity 速度 in place of acceleration for assessment of damage extent, although the physical significance of velocity is not clearly understood

Dynamic soil–structure interaction 地盤と構造物との動的相互作用
Fault movement 断層運動

2. Liquefaction causes the following problems and poses topics of study:

Effects of local geology on liquefaction potential 表層地質が液状化の可能性に及ぼす影響,
type of soil 土の種類, age of soil 堆積後の年代
Loss of bearing capacity 支持力の喪失 and subsidence of surface structure 沈下・めり込み
Floating of embedded structure 埋設構造物の浮き上がり
Boiling of sand and water 噴砂と噴水
Consolidation and subsidence 圧密と地盤沈下

Liquefaction is the build-up of excess pore water pressure 過剰間隙水圧 due to cyclic shear loading. When this pore pressure dissipates 消散する like consolidation of clayey deposits, the volume of sand decreases and ground subsidence 地盤沈下 occurs.

Lateral flow of ground 側方流動

Liquefied ground flows laterally and deforms in the meantime, causing damage to many underground facilities. This is the most recent topic of study and many people are trying to demonstrate the cause of lateral flow as well as to predict the amount of flow.

Soil–structure interaction 地盤と構造物との相互作用
Prevention of liquefaction 液状化の防止
Mitigation of liquefaction-induced damage 被害の軽減

It is still difficult to prevent liquefaction over a vast area where networks of lifelines are installed ライフライン網のような広大な施設全域で液状化を防止するのは不可能である. It is also expensive, or impossible in developed urban areas 都市域は建て込んですでに地盤を改良する余地がない. When this is the case, the bad consequences of liquefaction should be minimized by using several mitigation measures このような場合、液状化の発生はやむを得ないが、被害をなるべく少なくするような方策を考える.

2.3 Schematic Diagram to Show Relationship Among Geotechnical Seismic Problems