

# The Behavior of Sand Soil under Middle Confining Pressure by Triaxial Tests

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## Abstract

The purpose of this study is to investigate the behavior of sand soil under middle confining pressure at the standard methods of triaxial compression tests. A series of laboratory tests are performed under drained and undrained triaxial tests conditions without measurement of pore pressure.

2004年4月から6月まで、カザフスタン国首都アスタナ市にあるグレミロフ・ユーラシアン国立大学研究員のブーケンバイエバ・ディナ氏が本学客員研究員として滞在した。カザフスタン国の地盤工学上の課題を解決するため、本学で指導をうけながら研究活動を行い、特に、中規模の拘束圧を受ける砂の三軸圧縮試験について研究を実施し、本論文にまとめられている成果を上げた。ブーケンバイエバ・ディナ氏は、滞在期間中、本学学生へ講演を行うほか、本学学生・院生・教職員と友好的な交流を深め2004年6月帰国した。

**Key words:** triaxial test, sand, middle confining pressure

## 1 INTRODUCTION

Construction of large-scale and unique projects demands more careful and detailed research physic mechanical and strength properties of soil ground. The basic hypothesis of the Soil Mechanics allows with the help of sample testing at the simple mode of deformation to receive the mechanical characteristics necessary for the decision of practical problems at the complex mode of deformation (М.Н. Гольдштейн. Механические свойства грунтов. 1979).

One of the most important engineering properties of soil is its shearing strength or its ability to resist sliding along internal surfaces within a mass. Shearing strength is the property which enables soil to maintain equilibrium on a sliding surface, such as a natural hillside, back slope of a highway or railway cut, or the sloping sides of an embankment, levee or earth dam. This strength materially influences the bearing capacity of a foundation soil, a retaining wall, bulkhead or other type of retaining structure. There is hardly any problem in the field of soil engineering which does not involve the shear parameters of the soil in some manner.

Correct determination of shear strength of a soil is one of the most difficult problems confronting a soil engineer. Part of the difficulty arises from the fact that shearing strength is not an intrinsic property of a given soil, but varies over a considerable range with varying conditions, such as density, moisture content and degree of consolidation. The general

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methods available for determining the shear strength of a soil include: Direct shear test, Triaxial shear test, Unconfined compression test, Laboratory vane shear test. The direct shear and triaxial shear tests on soils usually fall into three main groups: 1. Unconsolidated-Undrained test (UU). 2. Consolidated-Undrained with and without pore pressure (CU). 3. Consolidated-Drained test (CD).

In this study, we will briefly discuss the comparative analysis of behavior of sand soil specimens in the triaxial compression test, by using common methods. The analysis is restricted to cohesionless soils that are tested when dry or fully saturated, but without measurement of pore water pressure. The experimental results were obtained at the Department of Environmental and Civil Engineering, Hachinohe Institute of Technology, within an ongoing international relationship (collaboration) between The L.N. Gumilev Eurasian National University (Astana, Kazakhstan) and Hachinohe Institute of Technology (Hachinohe, Japan). Tests were carried out in full accordance with the Standards of Japanese Geotechnical Society for Laboratory Shear Test.

Standards of Japanese Geotechnical Society for Laboratory Shear Test are one of the progressive and advanced methodical manuals. It includes sixteen Japanese Geotechnical Standards (JGS) and one Japanese Industrial Standard (JIS) in English concerning the laboratory shear test and deformation test. Since the 1960's, the Japanese Geotechnical Society has published more than eighty issues of the Standards of Japanese Geotechnical Society, and the Society has borne a substantial responsibility for Japanese Industrial Standards related to geotechnology ever since their establishment in the 1950's.

## 2 TEST PROCEDURES

### 2.1 Physical Characteristics of Testing Soil

The sand soil was tested in this work. Name of soil according with ASTM classification is poorly-graded sand with gravel SP or  $SP_u$  according with Japanese soil classification. The sand has a maximum grain size of 2 mm, a minimum grain size of 0.075 mm, an uniformity coefficient of 3.85, a concavity coefficient of 0.84, a specific gravity of soil particles of 2.855 g/

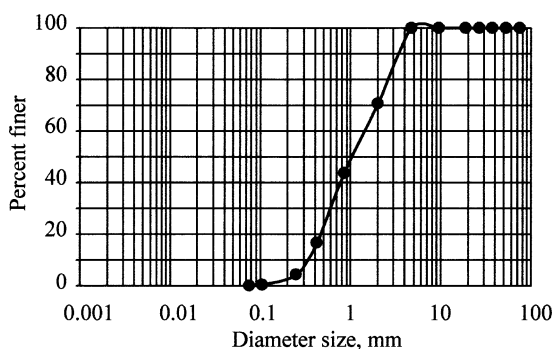


Fig. 1. Grain size distribution curve of sand soil

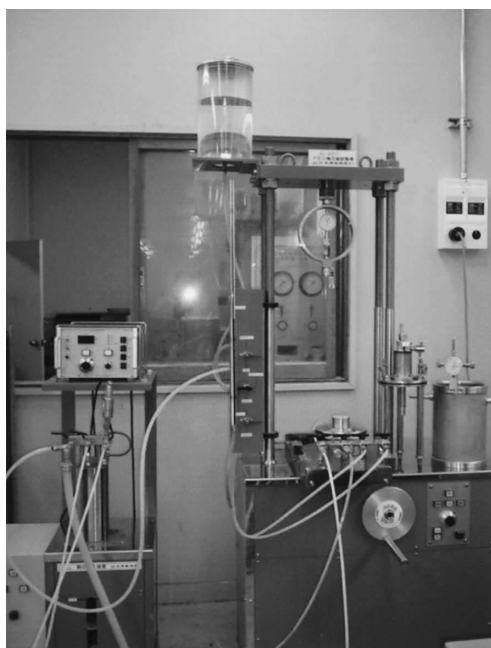


Fig. 2. Triaxial compression machine

cm<sup>3</sup>, void ratio of 0.882, moisture content of 15.44%. The grain size distribution of the sand is shown in Figure 1.

In a Fig. 2 is shown the triaxial compression machine with which help experiments were executed.

## 2.2 Sample Preparation and Test Procedures

All shear tests were performed in a conventional triaxial cell under drained (CD test) or undrained (UU and CU tests) conditions. The specimens were initially saturated. Saturation process was achieved by letting de-aired water flow through the bottom drainage line, and fills the voids in the specimen, being escaped from the top drainage line. The diameter of specimens was nearly equal to 5 cm, the height-diameter ratio being about 2. The UU, CD and CU tests were performed under cell pressure  $\sigma_3$  of 200 kPa, 400 kPa, 600 kPa and 800 kPa respectively. The experiments were carried out at a constant cell pressure and a constant axial strain rate. During the test, axial deformation and volume change were measured ; pore water pressure was not measured.

## 3 EXPERIMENTAL RESULTS

### 3.1 Results of Unconsolidated-Undrained Triaxial Shear Test

The standard undrained test is a compression test performed under constant cell pressure. The minor principal stress  $\sigma_3$  was maintained at a constant value while failure resulted from

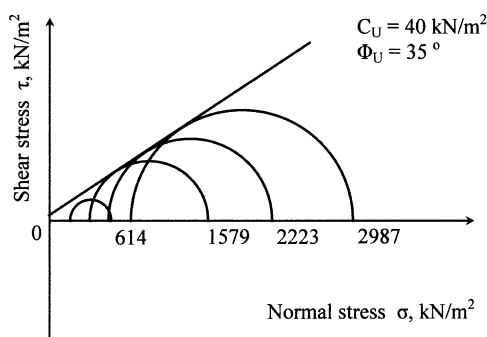


Fig. 3. Mohr's circle diagram for unconsolidated-undrained triaxial shear test

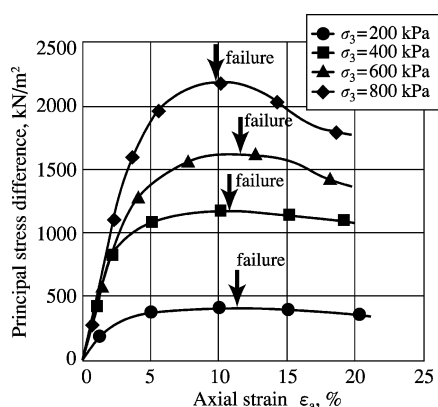


Fig. 4. Stress-strain curve from UU test

the increase in the major principal stress  $\sigma_1$ . The Mohr envelope for a series of UU tests on sand specimens is shown in Fig. 3.

Fig. 4 shows the relationship between a principal stress difference ( $\sigma_1 - \sigma_3$ ) and axial strain  $\epsilon_a$  of the UU test. The first sand specimen was failed at the  $\sigma_1 = 414$  kPa; second sand specimen was failed at the  $\sigma_1 = 1,179$  kPa; third sand specimen was failed at the  $\sigma_1 = 1,623$  kPa; fourth sand specimen was failed at the  $\sigma_1 = 2,187$  kPa.

A sliding surface was only found on the UU triaxial test under cell pressure  $\sigma_3 = 800$  kPa. Direction of shear surface is top-left to bottom-right.

### 3.2 Results of Consolidated-Undrained Triaxial Shear Test

The standard consolidated-undrained test is a compression test in which the three sand specimens were first consolidated under an all-round pressure  $\sigma_3$  in the triaxial cell before failure was brought about by increasing the major principal stress  $\sigma_1$ . The Mohr envelope for a series of CU tests on sand specimens is shown in Fig. 5.

Fig. 6 shows the relationship between a principal stress difference ( $\sigma_1 - \sigma_3$ ) and axial strain

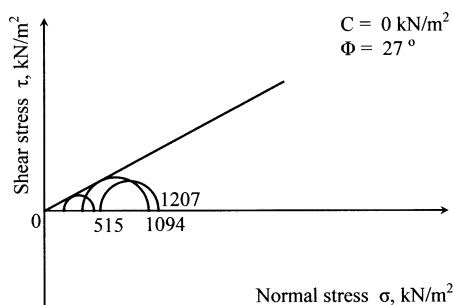


Fig. 5. Mohr's circle diagram for consolidated-undrained triaxial shear test

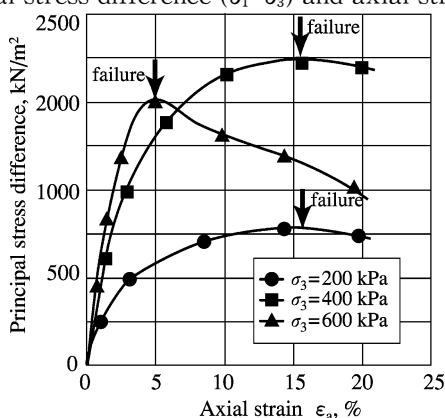


Fig. 6. Stress-strain curve from CU test

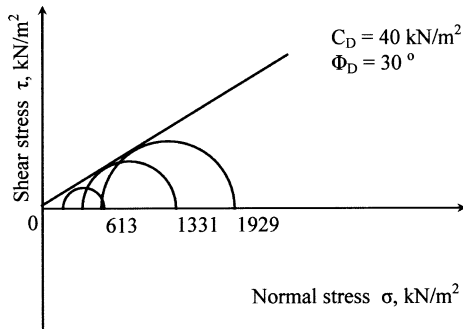


Fig. 7. Mohr's circle diagram for consolidated-drained triaxial shear test

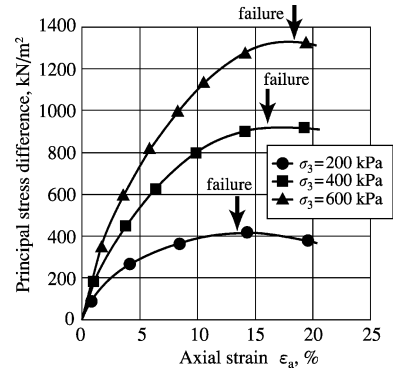


Fig. 8. Stress-strain curve from CD test

$\epsilon_a$  of CU test. The first sand specimen was failed at the  $\sigma_1=315$  kPa ; second sand specimen was failed at the  $\sigma_1=694$  kPa ; third sand specimen was failed at the  $\sigma_1=607$  kPa.

### 3.3 Results from Consolidated-Drained Triaxial Shear Test

The standard drained test is a compression test in which the three sand samples were first consolidated under an equal all-round pressure  $\sigma_3$ , and was then caused to fail by increasing the axial stress  $\sigma_1$  under conditions of full drainage. The Mohr envelope for a series of CD tests on sand specimens is shown in Fig. 7.

Fig. 8 shows the relationship between a principal stress difference ( $\sigma_1-\sigma_3$ ) and axial strain  $\epsilon_a$  of CD test. The first sand specimen was failed at the  $\sigma_1=413$  kPa ; second sand specimen was failed at the  $\sigma_1=931$  kPa ; third sand specimen was failed at the  $\sigma_1=1,329$  kPa.

Actually this test may be more realistic for many projects, such as the final soil-stress condition ; however, the unconsolidated-undrained or consolidated-undrained tests may provide more realistic soil-strength parameter values during the construction period when rapid changes in surface loading conditions may be occurring.

## 4 CONCLUSIONS

(1) The deviator stress at failure is found to increase with cell pressure. This increase becomes progressively smaller as the air in the voids is compressed, and ceases when the stresses are large enough.

(2) The magnitudes of the shear strength parameter - cohesion  $c$  are equal, received on UU and CD triaxial shear tests ; angle of internal friction  $\phi$  varies within of 27 to 35 degrees, obtained from UU, CU, and CD test.

(3) The drainage's conditions have an influence on the behavior sand soil.

(4) In the case of large-scale construction the residual strength after soil's failure must be consider.

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